Digital literacies and competencies: Examining teacher candidates’ achievement, engagement, attitudes, and personalized learning in technology enhanced environments

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A thesis submitted in partial fulfillment of the requirements for the Master of Arts degree in Education

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DIGITAL LITERACIES AND COMPETENCIES OF TEACHER CANDIDATES

Abstract

Teachers and students are increasingly operating in classrooms where the presence of digital technology impacts both parties across numerous facets related to teaching and learning. In an attempt to comprehend this dynamic, the current research aimed to understand the relationship from the perspective of the educator, acknowledging that today’s teachers are tasked with guiding students to become global, 21st century citizens who are capable of appropriately engaging with the opportunities and challenges put forth by digital technology. Therefore, this research aimed to examine teacher candidates’ (TCs’) a) attitudes towards digital technology, b) ability to manifest personalized learning experiences, and c) personal engagement and achievement outcomes. To address these aims, the research utilized secondary data related to digital competencies and digital technology experiences of TCs in a teacher education program at a Canadian university. Both quantitative (surveys) and qualitative (interviews, coursework) data were analyzed to determine overall impact. Findings suggest that TCs’ experiences with digital technology positively affected both their attitudes toward and uses of digital technology. Additionally, TCs’ levels of engagement with subject content was heightened when combined with digital technology, as well as their abilities to foster personalized learning, and enhanced achievement through knowledge construction and knowledge mobilization.

Keywords: digital technology; digital competencies; digital literacy; teacher education; teacher candidate (TC); personalized learning; 21st century teaching; 21st century learning
Summary for Lay Audience

This study focused on understanding how digital technology impacted the lives of teacher candidates (TCs). To address this research inquiry, data was extracted from surveys, interviews, and coursework. Data touched upon numerous areas, such as reflections on digital technology and digital technology usage, understandings of digital technology and digital literacy, and experiences with creating digital timelines for a course assignment as a means of working with digital technology. Findings indicate that TCs were impacted on a number of fronts as a result of their experiences with digital technology.
Co-Authorship Statement

This study relied on the interpretational use of secondary data. Data was previously collected by Dr. Isha DeCoito for a different study. All sources of data used in this thesis are highlighted under the ‘Findings’ section. Data sources include: three surveys and questionnaires; seven in-person interviews; and three examples of coursework (digital timelines), all of which belong to and are maintained by Dr. Isha DeCoito. Corresponding appendices – identified under List of Appendices – are attached at the conclusion of this thesis.
Acknowledgements

I would like to express my deepest appreciation and gratitude to my supervisor, Dr. Isha DeCoito, for her role in my research journey. At every step of the way, she offered her full expertise, her constructive support, and her guidance to ensure that I would depart my studies having met my personal and professional goals. I am incredibly grateful to have had an advisor that demonstrated the patience, encouragement, and availability I needed to help me manage the queries and concerns I had along the way.

I would also like to thank the members of my examination committee. As I sought to produce research that matched the expectations of graduate-level and professional field standards, their critical feedback and suggestions were immensely helpful in working to create purposeful research.

I would like to acknowledge the faculty members, colleagues, and friends I met during my time in the program. It was an absolute pleasure to have become acquainted with such intelligent, eloquent, well-versed, and vastly experienced individuals that offered meaningful and diverse perspectives to consider about education. I am thankful for the thought-provoking conversations, as well as the light-hearted moments in between.

Finally, I must acknowledge my family. I was fortunate, and in many ways, privileged to have grown up in a familial environment where I never had to question or be reassured of the love and support that I had in my life. Throughout the years, my parents made numerous personal sacrifices to maintain their family and ensure the best opportunities for their children. Although my decision to pursue graduate schooling was one I made for and supported myself, it is no doubt the product of all the selfless parenting and moments of unconditional support that came before it. For this, I am forever grateful.
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Introduction

It is quite evident, if not unanimously and inherently accepted, that education and schooling – both historically and in their contemporary states – are constantly evolving. The approaches to both pedagogy and curriculum have seen dynamic changes over time as education and the stakeholders within educational environments reacted towards technological advancements (Harasim, 2017). This has propagated a shift in education towards more digital, personalized, and learner-centered pedagogies. The young learners of modern classrooms, much like learners of the immediate past, have grown up in a globalized world where technological innovation and digital devices are omnipresent (Bayne & Ross, 2007; Wash, 2014). The presence of digital devices, be it through the form of cellular phones, computers, tablets, or even video game consoles, have not just permeated educational spaces but have solidified their presence as a powerful tool and resource for educators to use to improve their own classroom practices (Robin, 2008), and better impact the academic well-being of their students.

Research pertaining to the presence of digital technology in education is not an emerging nor untapped field of knowledge. In fact, it would appear that, at first glance, because of the plethora of accessible research and literature on digital technology in education and schooling, the field is saturated with literature and other examples of research that have thoroughly explained all we – as researchers, as educators, and as other interested stakeholders – ought to know about the relationship between digital technology and education. However, beyond that surface and upon greater attentiveness, there is still room to further explore existing knowledge and academic research studies. This means that there are also opportunities to discuss potential implications and direction for where the conversation around digital technology in educational research and education knowledge is headed.
Scope, Context, and Purpose

I approach my research from the perspective of an educator. Although not currently practicing in the classroom or the school, I write from the experiences that I have had in classroom settings, and I am working from the perspective of personal experiences and ideas that I feel are important to reflect on within my pedagogical and curricular choices. Additionally, I want to highlight the importance of this research to me as an individual who is not so far removed from being a K-12 student, and as an individual who has grown up surrounded by the wide-scale and ubiquitous presence of digital technology. I have seen the developmental changes and technological progression in classroom settings, in addition to the corresponding, tangible impacts. This has been demonstrated through participative actions or increased levels of student achievement, where familiar digital devices are tools for students to use in the classroom.

The context behind this research is of personal importance, as is my motive to become familiar and embedded within educational research centered on my interests so that it may assist me in transitioning to becoming a more modern and professional educator. I believe that research situated in this area can be beneficial for all stakeholders in education. As time progresses, it appears logical that education should simultaneously be progressive and attentive to the shifts of society. As Giannakos, Divitini, and Iversen (2017) contend that students must develop 21st century skills, such as critical-thinking and innovation, I am inclined to believe that teachers and educators must also be equally as knowledgeable and as fluent in order to help students achieve better schooling outcomes.

Thus, the purpose of this research is to further explore factors that affect teachers and students in classroom environments that are constantly changing, spearheaded by technological
innovation and the growing demands and needs of 21st century students. I am interested in seeking out how teacher agency can improve teachers’ classroom practices and better engage the students they work with during their professional careers.

**Statement of Problem**

It can be stated, therefore, the focus of this research are the digital technologies that teachers use in their practice; more specifically, examining how they are impacted by digital technology and how impacts may manifest. Where digital technology is increasingly promoted and steadily relied upon as a tool for participation in society, it is imperative to be cognizant of the impacts of digital technology as it may inform how teachers continually develop literacy of and competency with digital devices and digital applications. The presence of digitality exists in virtually all spaces and environments beyond school institutions, especially the home, for students and teachers. It is with this in mind that research dedicated to exploring how digital technology may affect certain competencies, skills, attitudes, and approaches to schooling and learning is a pathway to probe for explanations related to challenges and opportunities presented by digital technologies.

**Researcher Positionality**

I want to acknowledge that my research is meant to curate existing knowledge and literature to create newer and more holistic discussions of phenomena within education. This is focused primarily on phenomena such as digital competence and digital skills, digital timelines, classroom engagement, and personalized learning. In understanding this, it entails that the structure and formatting of these questions are not meant to necessarily probe unique discoveries or seek out new, original knowledge. Rather, they are meant to serve as guiding ideas that contribute to the current and ongoing discussion. The aim is to examine each of these
phenomena and attempt to demonstrate where they connect, intersect, and overlap and build on literature that explore the current findings and explanations that have been addressed by past queries, similar to my own.

I have reflected on my position as an educator and designed the research questions so that potential explanations and solutions that emerge upon formally addressing them may be interpreted as suggestions and ideas to incorporate in both pedagogical and curricular practice. The questions explore teacher experiences with digital technology, so that it may inform my understanding of teacher decisions within the classroom and how it ultimately impacts academic prospects and student potential.

Below are the key research question, and sub-questions that have piqued my professional curiosity and have had an influence on my practice as an educator. They are:

1. Does employing digital technologies impact teacher candidates' (TCs’)
   a) personal engagement (i.e., subject content, digital devices, digital applications)?
   b) personal achievement (i.e., statistical outcomes, learning processes, goals)?
   c) attitudes towards digital technology?
   d) ability to personalize learning?

2. If so, how are the impact(s) manifested?

I have selected these questions primarily because they will not only build on current research and knowledge but may also help address the importance of future research that explore existing gaps in the literature and other related queries.
Significance of the Study

In connection to the statement of problem, the significance of this study, therefore, is to highlight the challenges and opportunities that emerge from the relationship between teachers and digital technologies present in their lives. It can be reasonably stated that the landscape of schooling has been impacted significantly due to the steady immersion of digital technology, meaning that the experiences of teachers and students are constantly evolving. This evolution inevitably affects phenomena and discourses such as achievement, engagement, subject content, and attitudes toward technology. Thus, educational stakeholders should be interested in familiarization with changes and alterations that accompany digital technologies. By exploring the relationship of digital technology and teachers simultaneously, it may assist in developing more complete and defined understandings of digital competencies and digital literacy.

Conceptual Framework and Theoretical Overview

I approached my research using a global competencies framework, with a specific aim of exploring how global competencies are reflected and directed within educational policy. Through global competencies, students and individuals become familiar with the necessary and essential tools that may assist them in situations across their lives, especially those in school, work, and family. The Council of Ministers of Education [CMEC] define global competencies as “overarching attitudes, skills, and knowledge that can be interdependent, interdisciplinary, and leveraged in a variety of situations both locally and globally” (CMEC, 2018, p.1). Similarly, global competence as a concept can be defined as a multidimensional capacity that allows individuals to examine issues, appreciate different worldviews, engage with others, and become responsible towards both the collective well-being of others and world sustainability (OECD, 2018). For Canada, the CMEC (2018) has articulated six broad competencies that build on the
21st century framework (Milton, 2015) and literacy and numeracy initiatives. The six competencies are critical thinking and problem solving; innovation, creativity, and entrepreneurship; learning to learn and to be self-aware and self-directed; collaboration; communication; global citizenship and sustainability. Given the expansive list of understandings for what global competencies are and what global competence pertains to, it is of importance in my research to signify where this framework may help to inform the literature, key topics, and areas of interest.

Literature on digital competence and digital skills can be informed by a global competency framework. Skills such as (1) critical thinking and problem-solving, and (2) communication, signal that individuals should be both critically and digitally literate to be able to communicate effectively across written and oral genres (Ontario Ministry of Education, 2017). By being mindful of the notion that global competencies are meant to be useful and resourceful for individuals in assisting them in daily situations, it becomes quite clear and more apparent that global competencies can be manifested and demonstrated through digital competence and digital skills. By acknowledging that individuals are growing up in a world where devices will be present at virtually all times in their life, global competencies help to further demonstrate the importance of individuals being skillful and competent using said digital technologies. In this thesis, the importance is evident through discussions of certain careers, situations related to recreation and leisure, and most importantly, schooling and institutions of education, all of which are heavily immersed in and influenced by technology. Thus, this aforementioned idea requires competent individuals – those judged by the standards of global competencies – to thrive in those settings.
Literature on specific digital technologies, notably on digital timelines, is also highlighted. While salient connections between digital technologies and my research questions are outlined more thoroughly when formally addressing the literature, it can be stated immediately that the interactions and experiences that individuals have with certain technologies bode well to shape how they interact with the world around them. Through a global competencies framework, I examine such interactions and experiences and demonstrate how they work to shape how individuals, for example, engage with others, and how individuals may start to employ a more collective-thinking mindset that influences them to think of not just themselves, but others. Students who are globally competent should be innovative, creative, and entrepreneurial in their experiences, and given that those skills embody risk-taking, imagination, creative processing, and spontaneity, among other qualities (Ontario Ministry of Education, 2017), suggests that all of those qualities are emergent when students are tasked to use, experiment, and engage with certain technologies.

Classroom engagement may perhaps be informed through a global competencies framework by realizing that certain scenarios of engagement involve students actively collaborating and working together, meaning that varying viewpoints, perspectives, and thought processes should be valued and respected in order to obtain individual or shared goals and objectives. When teachers and educators make new and unfamiliar pedagogical and curricular choices and decisions aligned with a global competencies framework, students should embrace any new attitudes, skills, and knowledge that they may encounter in order to provide them with the best outcomes for their learning success.

Finally, personalized learning can be informed by global competencies in different ways. In understanding that being globally competent entails being cognizant and aware of local and
global issues, opportunities exist to connect with the needs and interests of students and to make those issues priorities for students in their education. Through understanding that personalized learning in contemporary times has previously demonstrated the potential to be highly digitized and intersect with technology (Izmestiev, 2012; Twyman, 2018), educators can reconceptualize both subject content and instructional design to familiarize students with the world around them so that they may cultivate students’ interests to be more aligned with those reflecting our society. Personalized learning is viewed as a form of self-directed learning. This is because students who are self-directed learners tend to be reflective and aware of their learning approach and thus, are able to self-regulate their different learning goals, especially those goals geared towards their personal life and career (Ontario Ministry of Education, 2017).
The Literature

To assist in establishing the level of familiarity with which I have approached my research in terms of my understanding of education and concepts related to educational research, it is important to identify and discuss different areas related to the questions of research and the topic itself. Literature that were consulted include: (i) digital competence and digital skills, (ii) forms of digital technologies and applications (i.e., digital video games, digital timelines), (iii) classroom engagement, and (iv) personalized learning. These comprise the determining frameworks that help to inform attitudes of technology, ability to personalize learning, personal engagement, and personal achievement. As previously mentioned, this will provide a knowledge base that will help to address the research questions and provide a rationale as to the relevance of my research.

Gaps in the Literature

Over the course of reviewing the literature centered on digital competencies and digital skills, there is a gap in research pertaining to the definition and understanding of what digital competence encompasses (DeCoito, 2018; Krumsvik, 2014). Even though there are sets of skills, abilities, and knowledges that may comprise the notion of digital competencies, there is still a need to narrow the definition of what should constitute digital competence in the context of teacher education. As well, measuring digital competence is another area where research is warranted in order to help understand and inform the literature in terms of what it means to measure teacher competence or skill levels (Ilomaki, Kantosalo, & Lakkala, 2011; Moreira-Fontán, García-Señorán, Conde-Rodríguez, & González, 2019). From a contextual viewpoint, there is a gap in research that pertains to digital competence and digital skills at the secondary school level. While there exists studies (Kong, 2014; Krumsvik, 2014) that have looked at
various aspects of digital competence and digital skill levels of teachers in secondary schools, it appears that they are in limited quantities in comparison to studies situated in primary and middle-school grades. Research that has been carried out on digital competence and digital skills in Canadian schools as a whole, let alone Ontario schools and specifically Ontario secondary schools, also appear to be scarce and untapped. This means that exploring digital competence and digital skills in a Canadian context and in Canadian classrooms, similarly to the study conducted by DeCoito (2018), may be a beneficial contribution to the existing knowledge and research on digital competence and digital skills.

There are many studies that examine various forms of digital technology, be it through computer and web applications, software and hardware, or other physical entities. For the purpose of this thesis, two digital technologies were explored: digital timelines and to a smaller extent, digital video games. Literature on digital timelines, while thoroughly defined and explored in a conceptual sense, has yet to explicitly examine the pedagogical effects of its usage in classrooms and other educational contexts. To clarify, while there is research that discusses, for example, the benefits of using digital timelines, there are very few case studies or examples of sustained research that more thoroughly observe the actual process of creating and using digital timelines and its corresponding effects on the educators that engage with them. When it became more apparent that I would be focusing on digital timelines, I performed a search using key terms related to presentation-based and timeline-based technologies. Notably, I searched terms such as “Prezi”; “Tiki-Toki”; “MovieMaker”; and “TimeToast”; in order to examine how they could facilitate the creation and presentation of digital timelines and how my study foci may have overlapped.
Research and literature on digital video games is not quite as untapped or unsaturated as digital competence and digital skills. DeCoito and Richardson (2016) examined a digital video game (DVG) and its relation to 21st century skills, finding the video game of focus, *History of Biology*, was instrumental in promoting skills such as communication, ICT literacy, and critical thinking, all part of a larger list of 21st century skills. Similarly, Arduini (2018) examined the effects of digital gaming on multimodal composition and concluded that further research examining DVGs may be needed. One common caveat about some of the studies that are shared by researchers is that they view their sample sizes as a potential limitation in their work (Arduini, 2018; Ball, Huang, Cotten, & Rikard, 2018; Beserra, Nussbaum, & Oteo, 2019; Gee & Esteban-Guitart, 2019). With this in mind, it suggests that a potential gap in the literature lies in the consistency of sample sizes in schools, which suggests that a larger volume of studies pertaining to the effects of DVGs connected to a wider range of students (perhaps those of different gender, race, ethnicity, socioeconomic status, etc.) should be conducted. Of the studies that are consulted surrounding DVG implementation in schools, most of the cases are situated in primary and middle grades, which suggests that looking at the implementation of DVGs in high schools can be important for expanding the literature in this area. The lack of research studies and literature in a Canadian context can be interpreted as a gap. However, because many studies have lobbied for and use commercial video games in their implementation, as well as knowing that commercial games may be more accessible for use than certain educational or culturally specific games, it may not necessarily invalidate the effects of the game, depending on whether students in one country are using it versus students in another country. This is reinforced by Gee’s (2010) assertion about how video game content can be changed, but the rules of the game
will remain a constant. In other words, similar studies with different game content can still render similar results if the rules of the game are not altered or modified.

In shifting the focus to classroom engagement, studies do not demonstrate or pinpoint any specific or glaring gaps in the literature. In recognizing this, some of the limitations discussed are related to the sample size (Bonvin & Sanchez, 2017; Remon, Sebastian, Romero, & Arauzo, 2017) and the teachers in the study (Perry & Steck, 2015; Remon et al., 2017). It can be speculated, therefore, that a potential gap is centered around studies that examine a narrower focus of students and teachers, based on the aforementioned limitations related to sample sizing. Another potential gap is the use of video games as a means of fostering engagement. While it is evident that most devices and applications, especially digital timelines and DVGs, can be effective tools for eliciting student engagement in classroom settings, additional studies that position digital timelines and DVGs as a central measure of engagement would be beneficial towards supplementing the literature, similar to the study conducted by Thomas (2017), which compared a games-based textbook with a print-based text. Once more, studies that are situated in high schools or in Canadian contexts are also limited, thus it is feasible to address the phenomena from the standpoint of personal relevance.

Finally, a review of the literature on personalized learning may also help to infer possible gaps in knowledge. There is a call to further take into consideration the points of view, perceptions, and self-identified limitations of teachers who are facilitating classrooms that use a personalized learning approach (Evans, Pruett, Chang, & Nino, 2014). As well, Hwang, Sung, Hung, Huang, and Tsai (2012), whose study include the use of personalized video games, believe that more experiments are needed to observe how video games can be used as personalized learning tools in schools. As a general sentiment, I speculate that more studies conducted on
personalized learning, specifically its effectiveness with different types of students, may be beneficial. This is echoed by Netcoh and Bishop (2017), who believe that one of the limitations of their study is the lack of diversity in their student sample size. Of course, as I have stated and reiterated, I believe more contextually relevant research situated in personalized learning geared towards the educational spaces that I am personally operating in would be useful, if not critical and beneficial, for this particular section of the literature.

**Digital Competencies and Skills**

To comprehend how teachers engage with digital technologies, it is beneficial to explore literature that not only defines the understanding of digital competence, but probes and discusses select skills, traits, or attributes that comprise the notion of what it means to be digital competent.

In reviewing research examining the presence of digital competence and digital skill levels in both teachers and students, there are many key findings to discuss. Of course, defining digital competence is an important entry point. Ilomaki et al. (2011) describe digital competence as a political concept – one which reflects the beliefs and wishes of future needs – and, additionally, reference the European Commission's understanding of the term, which recognizes digital competence as integrated technology being used confidently in an array of settings, such as work and school. Digital competencies are additionally defined as competencies required by citizens for personal fulfillment, social inclusion, active citizenship, and employability in a knowledge-based society (Gutiérrez & Tyner, 2012). Both of these definitions differentiate from another related term, *digital literacy*, which descriptively highlights the process of understanding, reproducing, and manipulating numbers and text through computers and digital devices (Ilomaki et al., 2011). It should be noted that digital literacy itself can also be regarded and understood as a digital competency (DeCoito, 2018). The shift in society’s growing reliance on
technology mandates that education emphasize technological and digital literacy including digital competence (skills, concepts, approaches, attitudes), digital usage (professional and disciplinary application), and digital transformation (innovation and creativity) (Belshaw, 2011 as cited in DeCoito & Richardson, 2017). Improving digital literacy underpins not only a nation’s capacity to provide individual groups with equity of access to social opportunity; it is a necessity for participation in the digital economy (DeCoito & Richardson, 2016). With this in mind, it can be inferred that digital competencies are fostered through strong senses of digital literacy and that increased exposure to devices and tools that require the use of digital literacies will lead to individuals becoming more digitally competent.

Teachers and their own digital competence and digital skill levels are an integral part of literature to consult in this specific area of research. It is generally understood that students expect teachers to be competent and supportive in not just their use of technology, but also in their willingness to try and use new and unfamiliar technologies (Buzzard, Crittenden, Crittenden, & McCarty, 2011). Beyond that, teacher familiarity with digital technologies that contribute to their digital competence should be explored. For example, analyzing teacher education in Norway reveal that digital competence has become a significant part of teacher education and developing digital competency is shifting towards being considered an important general teacher competence (DeCoito, 2018; Krumsvik, 2014). Additionally, a study in South Africa (Chigona, 2012) where digital storytelling was used as an exercise for pre-service teachers allowed for their own digital skill levels and competence to be called into action. Digital storytelling in this context, according to Sylvester and Greenidge (2010) as cited by Chigona (2012), is a combination of several elements such as point of view, emotional content, voice, among others. Given the breakdown of their task, preservice teachers were asked to discuss their
perception and use of digital storytelling based on their own experience using it in their teacher education program. Participants in this study were able to use this teaching approach to (i) develop their practice more personally and professionally, (ii) help challenge issues within their classrooms (such as diversity), (iii) gain similar insights from other digital stories, and (iv) better connect and get along with peers (Chigona, 2012).

It should also be noted that the presence of digital competence and digital skills should be clarified and identified. Digital competence and digital skills can be fostered through many different mediums and various modes, in addition to being exemplified through different forms.

Digital infographics, as a measure to assess web familiarity and practice with a particular digital mode, were examined by Matrix and Hodson (2014). After administering two assignments at two different Canadian universities that were connected using digital infographics, there were several key insights that helped inform digital competence and digital skills in terms of their connection with schooling. The process of completing the infographics assignment contributed to students becoming more self-directed, more engaged online with their peers, while additionally providing a great opportunity to work with digital technology and traditional textual modes simultaneously and encouraged students to further participate in digital environments and cultures.

Curation is another skill that teachers should not only be familiar with but also be able to use quite readily, considering that students must also be proficient at curating when using digital technology. Mihailidis and Cohen (2013) discuss a notion that pedagogical models should aim to empower critical thinking in students (those who work in digital realities), acknowledging that students have significant reliance on search engines and social media. Whether students curate through ‘tagging’, such as using hashtag symbols (#), or through carefully arranging content in
organized lists, students are exemplifying traits of being digitally and media literate in this process. On this note, it reinforces that modern educators must also be fluent in curation and ought to incorporate opportunities within their practices to help students continually develop these skills.

Similarly, the use of digital pens and interactive whiteboards (IWBs) is worth noting. In a classroom study in Sweden, Alvarez, Salavati, Nussbaum, and Milrad (2013) revealed numerous findings regarding the effectiveness of digital pens and IWBs. Among these findings, one particular discovery was that there were no major lags or extensive training time needed for effective use of either tool within the classroom. Alvarez et al. (2013) highlighted the fact that any issues with digital pens or IWBs could be remedied quite easily and that the integration of these digital technologies saw positive improvements in the classroom, which included improved cognition literacy and increased subject content proficiency.

In sum, even with the potential caveat pertaining to the time and effort it may take for technological adaptation, as well as confronting the unfamiliarity of working with new devices, there is still great interest and importance for educators to be digitally competent and possess necessary digital skills that assist them in their own practices and impact their students. When implemented and integrated into curriculum correctly, students are typically affected in a positive manner which assists in creating better classroom experiences for both parties. Hence, there is still a need for teacher training in the areas of digital competence and digital skills (Kong, 2014), and establishing more clear-cut ideas and standards for what is meant by digital competence and digital skills.
Digital Timelines

Presentation-based approaches, such as digital timelines, are an effective digital resource to use in classroom settings. Timelines have been used as a method to allow digital archives to present material in intuitive frameworks (Enis, 2014). Evans and Bradley (2019) present numerous capabilities that digital timelines offer, including: situating events in context; highlighting new developments; categorizing events and relationships; explaining processes and procedures in a visual way; and showing development and exhibiting growth.

Much of the effectiveness of digital timelines can be linked to the software or programs that are used to create them. Typically, software that is geared toward making digital timelines, such as Tiki-Toki, TimeGlider, and TimeToast, are all adequate digital resources. Alternatively, presentation-based software, such as PowerPoint or Prezi, can also act as viable programs for creating digital timelines. Prezi is able to facilitate many of the capabilities that make digital timelines such lauded presentation-based learning resources. Narayanan (2017) highlights that teachers face a conundrum related to facilitating student motivation and posits that using programs like Prezi, offer different templates which are suited to meet specific goals and creative visions. In recognizing that students are able to understand concepts far better when content is presented in unique ways, Prezi is a solution geared at impacting student motivation. Among oral presentations using PowerPoint and Prezi, students found Prezi to be more visually compelling, organized, engaging, and persuasive, with students ranking Prezi-using presenters as more knowledgeable and more professional than PowerPoint-using presenters (Moulton, Turkey, & Kosslyn, 2017). However, in comparing Prezi with PowerPoint, Chou, Chang, and Lu (2015) noted that while Prezi was more effective as an instructional medium for knowledge acquisition, PowerPoint demonstrated instructional benefits related to long-term learning retention.
Case examples of digital timelines provide implications as to their benefit as resources, as well as informing the nature of how timelines can work. Dennis and Belshaw (2013) examined a software called Beedocs Timeline 3D. They noted that through the software and its interactive features and elements that could be used to build the timelines, the software was effective in helping students learn at their own pace. They suggested that Tiki-Toki, another digital timeline software, could also operate just as effectively as Beedocs Timeline 3D.

In another case study examining digital timelines as frameworks for meaning-making, it was noted that motivations for meaning-making were based on sharing personal lives with peers and self-recollection. Among the findings, it was learned that audiences played a role in influencing the content of the timelines; templated-timelines clashed with meaning-making; conveying certain narratives clashed with authenticity; timelines enabled personalized approaches; and while time could be a vehicle for reminiscing, the removal of time could enable more flexibility with the project (Thiry, Lindley, Banks, & Regan, 2013).

**Digital Video Games (DVGs)**

DVGs are consumed at gargantuan weekly rates, with close to three billion collective hours spent playing online games by individuals (McGonigal, 2010, as cited in Aust, Nitsche, & Pelka, 2014). DVGs also tend to reach a wide audience and are able to enact learning experiences, with statistics indicating that this is true for around 90% of girls and close to 100% for boys (Granic, Lobel, & Engels, 2013; Hays, 2005, as cited in DeCoito & Richardson, 2016). Much more than that is the presence of identity and how individuals who play video games have emerged as “cyborgs”, signaling that their gameplay experiences move beyond their gaming device and shift into many other devices, such as computers, that are used to search for game-play assistance or other devices used to continue playing the game (Arduini, 2018). Citing Keller et al. (2008),
Arduini (2018) adds that gaming consoles, as opposed to computers, provide less intimidation to technological experimentation, and that gaming helps to serve as a gateway into programming.

DVGs are understood and conceptualized as different entities and ideas. Besides being colloquially understood as commercial items that individuals may purchase for their own entertainment or recreational value, DVGs are (i) narrative spaces that players or users inscribe with their own intent (DeCoito & Briona, 2020; Steinkuhler, 2010); (ii) challenging problems to solve (Gee, 2018); (iii) digital invitations to rich, social interactions (Gee, 2012a); (iv) artificial environments that are rule-based, responsive, and cumulative (Meyer, 2011, as cited in Ball et al. 2018); and (v) spaces where ideological logic, digital technologies, and individuals all meet and intersect (Kelly, 2017). Further explored, video games can be categorized into separate unique groupings and genres. Such groupings include drill-and-practice games, where tasks are isolated, broken down and mastered, and problem-and-goal games, where users set their own independent goals or learn by participation where and when clear goals have been set for them (Gee, 2013; Gee, Hayes, & Jenkins, 2013 as cited in DeCoito & Richardson, 2016). Depending on what type of goal or learning objective educators may have planned for in their lesson, if DVGs are being utilized as tools for facilitating learning, understanding what types of DVGs to use, whether they are drill-and-practice or problem-and-goal, is essential for achieving the desired results when students engage with the technology.

In recognizing all of this, it is important to emphasize some of the outcomes that may arise from playing various types of games. Gee (2012a) contends that certain games may teach students about many different situations or expand on different knowledge capacities, which includes history (if individuals are playing a game set in a historical setting), sustainment (if individuals are playing games such as *The Sims*), literacy and numeracy (if individuals are
playing digital card-trading games) and working collaboratively and strategically in a team setting (if individuals are playing games such as *World of Warcraft*).

It is important to clarify that the content of games does not necessarily alter the problems, goals, and aims of the game, which ultimately means that games can always provide lessons to be learned and knowledge capacities to be expanded. For example, a game like *Grand Theft Auto* may task individuals playing the game to play in a stealth-like manner to plant a bomb, which at initial glance does not seem to provide an authentic or beneficial learning moment. But if the scenario were to change and users were tasked to, instead, sneak into a loved one’s vehicle to place flowers, the individual playing the game, although playing and engaging with different content, would still be following the same, essential rules and the learning outcomes are still achievable (Gee, 2010). With this in mind, if teachers and educators are able to understand how DVGs can be allegorical and foster these covert, hidden, but existing learning opportunities, it is simple to realize the value in incorporating commercial and non-educational games in their classroom, especially if certain commercial games are popular among students.

However, beyond defining what video games are and how their content can or cannot be positively related to education, there are other beneficial effects and impacts that emerge from DVGs that influence students, teachers, and educational spaces. In one particular case, language learning motivation was significantly impacted by the use of video games in a learning environment. In a study where students were divided into three groups – players of the game, observers of the players, and readers of the game’s storyline – all groups of students had an increased sense of motivation towards learning English after being exposed to the video game in their class (Ebrahimzadeh & Alavi, 2017). Where a commercial game may have normally been used for recreation or seen as a means for entertainment, it has instead been used as a tool to
gradually motivate students to play the game to better understand a second language. In fact, it is not uncommon for commercial video games to be used in such a way due to their ability to impart communication skills, adaptability, and resourcefulness in students (Ball et al., 2018). In a study exploring students of different socioeconomic status and digital fluencies, Ball et al. (2018) found that video games can contribute to shortening the gaps that exist between students who are fortunate to possess many digital resources (which may contribute to increased digital competence) versus minority students who did not have access to the same resources.

The influence of DVGs is equally important to observe in the context of how they work to shape students and individuals into being more collaborative and engaged when working together. As it turns out, there are several ways that video games can demonstrate just how powerful and influential they are in fostering collaborative settings. For example, it is paramount to discuss the natural spaces that form which are described as “affinity spaces” that bridge and bring individuals together through video games (Gee, 2012a, 2018; Gee & Esteban-Guitart, 2019). These spaces are where the work of teaching, learning, and knowledge transfer are present and where many different individuals take on various roles, such as teachers, mentors, and students, within these spaces. The significance of these spaces is that they are not bound by time and space; they can be physical spaces (such as a school) or virtual spaces (such as an Internet forum) where collaboration and engagement are taking place (Gee, 2018). Individuals may share experiences and stories from gameplay, share tricks that modify how to play and engage with the game, and share other related discourse with other individuals, which when taken together, contribute to heightening the experience for all players. In understanding this, it becomes pertinent for teachers and educators using DVGs to carefully consider cultivating and curating the correct affinity spaces within their classrooms in order to maximize and support the
digital learning experiences of their students. This is especially true because it is not race, gender, or class that bring people together within these affinity spaces; rather it is the collective passion shared by individuals stemming from the game (Gee & Gee, 2017). By understanding this, it becomes more evident, if not glaring, that DVGs are a democratic form of digital technology to use in the classroom and are able to elicit a wide range of student responses and actions when managed appropriately.

It must be noted that despite the breadth of positive implications that result from using DVGs within the classroom, teachers and educators must still be aware of some potential drawbacks. For example, Beserra et al. (2019) warn that even if DVGs are highly critical and crucial to increasing engagement and positive behavior upon implementation, teachers run the risk of increasing off-task behaviors in students as the school years progress if the games are not updated, altered, or changed. Circling back to an earlier part of the conversation regarding commercial games and educational games is the notion that educational video games are often perceived as “boring” (Kinzie & Joseph, 2008 as cited in Ebrahimzadeh & Alavi, 2017). This notion, along with earlier ideas of curation, suggest that teachers must be meticulous and careful in terms of which games they choose to use and should consider the interests and needs of their student audience when integrating digital games within the classroom. As well, any issues that teachers experience with the use of DVGs must be dealt with appropriately, as their own feelings of frustration with video games may take away from potential positive outcomes for students (Moline, 2010).

To recap, DVGs are far more than just commodities of entertainment. They should be interpreted as problems to solve and not solely just as a type of content (Gee, 2012b). In educational spaces, they have emerged and have gradually evolved into everyday mediums and
modes of digital technology that have modified instructional design, lesson content and activity, and assessment options. However, while they are expansive, teachers and educators must still maintain competence with how they choose to work with DVGs by being aware of some of the potential negative effects that can result if games are not managed and integrated appropriately.

**Classroom Engagement**

It is essential to define what is meant by engagement. For example, one definition suggests engagement is the state in which students are emotionally ready for their learning task and perceive what they are about to learn as both important and relevant (Marzano, 2011, as cited in Deitrich & Balli, 2014). Based on this understanding, there is an opportunity to investigate this area of research conceptually and to contextualize engagement (as it relates to digital technology). This is possible by exploring different ideas and literature which discuss student engagement when digital technology is used by educators or is present in the classroom. It is noteworthy to state that most of the literature discussed and presented on classroom engagement is situated in classrooms that are heavily enamored with digital technology.

Exploring the role of the educator or teacher is a helpful starting point. Since teachers’ digital competence and digital skills were previously discussed, the next section of literature will focus on where competence and skills may intersect and impact classroom engagement. One case that examined both digital competences and engagement focused on the “iTECProject” that was piloted in 2000 schools in 19 countries. The iTEC Project was comprised of three competence-related tools and aims: *Eduvista* – designing and sharing future classrooms scenarios, *Edukata* – innovative learning activity design, and *Eduteka* – technologies that would be used for advanced learning activity design (Pedro, Matos, & Pedro, 2014). Over the four years in which the pilot took place, the effects of the pilot resulted in students developing more
positive attitudes towards learning, students becoming more engaged with their schoolwork (a notion that was supported by close to 80% of teachers involved in the study), and teachers themselves discussing that they felt they were more knowledgeable and open to using ICT knowledge and skills in their pedagogical choices and classroom activities (Pedro et al., 2014). While just one study, it demonstrates and further supports the links between digitally competent teachers and students synergizing well with digital tools in a classroom environment. Teachers, when using digital technology for engagement, must also be prepared to shift their roles from being a central part of the classroom instruction to a facilitator that assists in implementing technology in classroom instruction (Deitrich & Balli, 2014).

In other cases where teachers or educators are not necessarily the focal point or central concern for understanding engagement, it is important to consult other examples where engagement is supported by the tools, devices, or technology being used. One example is a study that used smartphones as clicker devices and personal tablets as interactive whiteboard substitutes. The rationale behind this decision is students’ familiarity with smartphones and tablets, with the authors noting that phones and tablets are able to offer flexibility, versatility, and function just as well as their replaced counterparts, while the reverse may not be true for clickers and whiteboards (Remon et al., 2017). In this particular study, there were many interesting findings that emerged from using everyday devices as replacements for traditional school technologies. Of these findings, the most important claim made by the authors is that student engagement, student interest, and even student achievement levels increased when teachers incorporated the electronic devices that students have a desire to use in the classroom (Remon et al., 2017). It is also noted that students in this study preferred interactive lessons and interactive examination preparations which suggests that teachers and educators should consider using
digital technology and electronic devices as often and as consistently as possible in the facilitation of their curriculum. Similarly, Perry and Steck’s (2015) findings support the notion of pads and tablets being used in the classroom, with results from the intervention revealing that behavioral engagement and self-efficacy increased for students who used tablets versus students who were part of the control group that did not use pads.

In another study where an educational video game, Classcraft, was used, classroom engagement was demonstrated. Classcraft is a game where students assume certain roles and engage with class management skills that dictate how their classroom experience may take shape (Bonvin & Sanchez, 2017). For example, if a student arrives late to their classroom, they may use the “invisibility” perk which means that the teacher did not “see” them arrive late and therefore, they are not reprimanded for arriving late. Bonvin and Sanchez (2017) state that this type of game was aimed at exploring social engagement within the classroom, as students could choose to use individual abilities which serve only the student themselves or collaborative abilities which would be geared towards serving the collective interests of the classroom. As it turned out, students were far more socially engaged with each other as most students recognized the collective benefits of using collaborative powers versus individual powers; the researchers did, however, note that collaboration and social engagement could vary among gender, the roles played in the game, and the classrooms themselves.

Examining texts that students are engaged with may also provide insight into defining classroom engagement. As a whole when considering texts, it is important for teachers to be attuned to multimodal literacies (Lenters, 2018), as highlighted in a research study that compared two different textbooks that appealed to different modes. The research study in question is predicated on the claim that some students are not engaged with textbooks outside of the
classroom (Stratton, 2011, as cited in Thomas, 2017), and that teachers are still unsure of the use of DVGs in the curriculum (Gros, 2017, as cited in Thomas, 2017). Therefore, when comparing the use of the two textbooks, a digital game-based textbook and a traditional text-based textbook, new knowledge emerged that helps inform knowledge on classroom engagement. Thomas (2017) states that after different groups of students had used either the digital textbook or traditional textbook, students spent more time and effort on their work and school tasks when using the digital game-based textbook than the students who were using the traditional textbook. Study findings also suggest that digital game-based textbooks have the potential to lead to higher performances in students (Thomas, 2017). In sum, this reinforces the notion that the role of texts within classrooms can be a significant indicator of classroom engagement, and if teachers and educators are interested in incorporating digital resources in their pedagogical approaches, their texts should likewise promote corresponding digital affordances.

To summarize, classroom engagement becomes evident when students are provided with opportunities to demonstrate how they learn or behave in their classroom settings. In classrooms where there is a steady or prominent digital influence, engagement can be dependent on how comfortable or motivated the students are to work with the available technologies and devices in their environment. Literature and research on engagement reveal that while traditional texts, devices, and technologies affect engagement, it is the more familiar and personalized devices that students are used to operating and using that are more proficient at increasing and sustaining engagement. Of course, much like DVGs, teachers should be cognizant of how and when to use certain digital devices in their classroom so as to not increase the risk of off-task behaviors or disengagement. As well, teachers should be as skillful as possible when using these devices in
the classroom, while also recognizing the opportunities to passively facilitate lessons while technology spearheads knowledge and content acquisition during the lesson.

**Personalized Learning**

The final area of literature I explore is personalized learning. In discussing the literature from the other areas, common themes that emerged suggest that student attitudes, their competence and skills, or their own interest levels in the classroom are important factors to consider when determining the effectiveness of digital technologies. Building on this notion, it is important to probe deeper into the existing knowledge surrounding personalized learning to further intersect and strengthen the links between the four other sections of literature that were previously discussed, namely digital competencies and skills, digital timelines, DVGs, and classroom engagement.

Personalized learning can be envisioned as a way to meet individual needs (The Next Generation Blended Classroom, 2016), and has been described as a process that is competency-based, self-paced, technology-powered, and one where students have an active choice in what they learn (Horn, 2017). Deed et al. (2014a) describe personalized learning as the sociocultural authorization of individual freedom in the classroom. Moreover, personalized learning can be comprised of three specific notions: student assessment, based on what teachers and students believe is important; personalized feedback, such as specific educational goals that are performance-related and informative-correcting; and deeper learning, expressed through skills such as independent thinking, analyzing, collaboration, and communication (Evans et al., 2014). Personalized learning, according to Horn (2017) is not an end goal or a final stop for students; it is instead a means to a greater goal, which is usually student success in the classroom.
Camacho and Legare (2016) discuss competency-based learning, which operates on the notion that accreditation should be awarded for evidence of student learning and not student time spent in the classroom, which reinforces the use of personalized learning in classrooms. In recognizing this, it can be speculated that where and when personalized learning is active, teachers may be shifting from traditional roles of knowledge and content providers to roles that are more facilitative towards fostering personalized student learning and student success. Part of recognizing and understanding personalized learning may emerge through a concept known as blended learning, which is defined as a formal education experience that has some level of an accompanying online component (Nickels & Gartner, 2018). Nickels and Gartner (2018) position that through blended learning, students are provided with meaningful and cognitively demanding activities which contribute to them becoming more aware of their individualized learning styles during those processes.

Naturally, it is worthwhile to further inquire into personalized learning by describing how it may be facilitated in schools. Deed et al. (2014a) cite a plethora of strategies and actions that can be undertaken that help explain how to best create environments for personalized learning. These strategies include teachers maintaining flexible use of time and space (Halpin, 2007; Leiringer & Cardellino, 2011); reforming the classroom as a community space (Usher, 2011); fostering reflexive interactions between students and teachers and between students themselves for the choices they make (Brannen & Nilsen, 2005); and pervasive use of technology to help students map their learning choices (Dabbagh & Kitsantas, 2012; Selwyn, 2009). By recognizing these strategies, Deed et al. (2014a) queried as to how teacher agency would be characterized in environments promoting personalized learning, which is active and enacted. The researchers discovered that students in this type of classroom were expected to be
collaborative and communicative with each other, in addition to using skills such as problem-solving and researching for their tasks. Students were to make use of both physical (the classroom) and virtual (online forum) spaces to complete their task; and teachers operated as co-regulators of the task by helping students plan for their task, mitigate off-task behavior, among providing other forms of assistance (Deed et al., 2014a). Much like approaches that were identified in the literature pertaining to classroom engagement, it becomes evident that the role of teachers and educators in personalized learning classrooms transform as students undertake more agency and autonomy for their learning goals.

Another study by Deed, Lesko, and Lovejoy (2014b) explored how teachers created personalized learning spaces by examining the implementation of two different learning methods: a game-based learning curriculum and self-directed learning curriculum. Findings reveal that in a game-based learning curriculum, teacher involvement was centered around encouraging teamwork, skill development, and social learning, while in a self-directed learning curriculum, teachers were more hands-off and operated as facilitators of the learning experience. The authors explain that considerations for personalized learning spaces should account for the time and space it takes for implementation, the necessary actions of adaptation, as well as being aware of the affordances for teaching and learning contexts for both teachers and their students.

Similarly, Netcoh and Bishop (2017) examined a case where teachers and middle-school students designed a personalized learning curriculum that catered to student learning interests. During this initiative, one of the major findings was that the decision to alter classroom learning to that of personalized learning reflected the fact that teachers had become better acquainted with their students. This led to teachers being able to (i) create a culture of support for all of their students who were working on personalized projects, and (ii) incorporate norms for positive
interactions within the classroom, while also freeing the teachers of typical curriculum constraints.

Conversation about additional applications of personalized learning in school settings will help to elucidate how personalized approaches function in educational environments. It is helpful to consider a study of a history class (Davis & Ash, 2011) in which students were provided with opportunities to be creative and exercise autonomy in terms of their learning. As students were tasked with creating a historical timeline, they were allotted the agency to choose what type of history they would demonstrate. For example, some students elected to create a timeline of “cool” shoes, incorporating old video clips and using different video styles, as a way to complete their task. Students in this class viewed this instance of personalized learning as positive because they felt more “passionate” about completing their work as a result of engaging with content of their choice.

In another study (Beemer, Spoon, Fan, Stronarch, Frazee, Bohonak, & Levine, 2018), a statistics course was offered to students in both an on-site and an online format. Comparing the two classes, the students who were enrolled in the online course scored seven points higher than students who were enrolled in the on-site format, despite predictions that they would score lower than their in-class counterparts. This allows for a possible inference to be made suggesting that when students are essentially studying “by themselves” – since they are working without formal lecturing, instruction, and the generalities of being in a physical classroom – it may potentially work to their advantage, furthering the notion that personalized learning is beneficial for student success.

The use of a personalized video game also demonstrates a form of personalized learning application in schools (Hwang, Sung, Hung, Huang, & Tsai, 2012). In this example, students
were provided two versions of a video game that were designed to meet their diverse learning needs in terms of learning curriculum content. One version of the game was programmed to be linear and sequential for learners who were most comfortable learning in that manner, while the other version was designed to be more global and geared towards students who preferred more holistic thinking and learning processes. The results indicate that both groups of students who played the game that corresponded to their preferred learning style had amassed equivalent knowledge, equivalent learning motivation, and higher degrees of technology acceptance. On the other hand, students who played the version of the game that was mismatched to their preferred learning style had less knowledge acquisition, learning motivation, and technology acceptance (Hwang et al., 2012). This reiterates that students, when provided with opportunities to work with content and tools that align with their specific learning style and needs may likely experience more academic success in their schooling. This claim is substantiated by Johnsen (2016) who states, based on a study conducted by the RAND Corporation, that student achievement is best supported by personalized learning when there is a presence of flexible student groupings, learning spaces that support the specific personalized learning model, and when students are able to discuss their personalized learning goals.

To understand personalized learning as a more holistic model or approach, it is helpful to examine a case in Spain where an entire school underwent a shift to transform their education to be more personalized (Paz-Albo, 2017). The Education: Basic and Interactive (EBI) Project sought to change curriculum for an entire school based on the needs and interests of the students, while making use of their own independent diagnostic assessments and prompts to measure the personal and academic readiness of the project for students (Paz-Albo, 2017). This model of learning produced many key findings, including the fact that students in an EBI setting were (i)
empowered to plan goals for multiple timelines, whether they were daily, weekly, or semesterly; (ii) provided opportunities to engage in goal-directed challenges and subsequent small-group feedback sessions for which they could use to adjust their goals; (iii) working collaboratively with their teachers where they could deliberate questions, problems, solutions, and knowledge transformation; and (iv) their own “creators” of knowledge while their teachers became “analysts” or “tutors”. As a result of the project, student achievement increased and students saw an increase in utilizing 21st century skills, namely problem-solving and critical thinking (Paz-Albo, 2017).

To summarize, personalized learning has emerged as a new, overarching influence that has transformed teacher approaches to both curriculum and pedagogy. For personalized learning approaches to work, it relies on teachers who are willing to cooperate with their students to help co-construct a curriculum that will help students achieve their specific learning goals. Teachers must be willing to adjust their own roles and be willing to function in ways that are more conducive to the goals and learning successes of their students. By being digitally competent, cognizant of the effects of digital resources, and understanding how to create cultures of engagement within their classrooms, teachers and educators may be able to use that knowledge to better create holistic personalized learning experiences for their students. Of course, it can be reasonably speculated that the challenge for teachers is to understand their students and assess the feasibility of implementing personalized learning initiatives to examine if it may, in actuality, impact their students in the way that it is intended.
Methodology

My research used secondary data for the purpose of analysis and discussion in order to address my research questions and ultimately, inform my research. The usage of secondary data itself had been analyzed and authors of the particular study for which I am referring to have put forth implications that discuss how researchers can position secondary data in their own studies. Ruggiano and Perry (2017) discuss three important recommendations to consider when using secondary data. That is, the use of secondary data needs to be clear and transparent in order to inform readers of its use or role in the study; the role of ethics in secondary data must be clearly defined; and increasing the presence of rigor and specific discussion of limitations of using secondary data in their studies. Therefore, there was a responsibility to incorporate dialogue that touched upon these three notions throughout the discussion of methodology in my research.

The data being utilized is from a previous study that was centered around digital competencies and explored TCs’ experiences with technology in a teacher-education science methods course at a university in Canada (DeCoito, 2018, 2020). The main interest in the study pertains to an assignment that tasked TCs with creating a digital timeline about the history of science. This assignment required that TCs blend their knowledge of science (biology/chemistry/physics) with their knowledge of technological devices, equipment, and software to create an end product that many of them had not created before, much less having awareness of what it was they were creating.

Obtaining Ethical Approval

Although each source of data (questionnaires and surveys, reflections, interviews, and coursework) had previously received ethical approval for the original study, obtaining new
ethical approval was a requirement in order to use the secondary data to meet the goals of my study. The process of obtaining ethical approval was facilitated by completing an ethics application through the Western University Non-Medical Ethics Board (NMREB). The purpose of the study, the aims of the study, and the research questions were all defined and distinctly different from the original study. A waiver of consent was requested from the NMREB in accordance with the Tri-Council Policy Statement 2, Article 5.5B (secondary use of non-identifiable information). All data (surveys and questionnaires, reflections, interviews, and coursework) in this study are anonymized and de-identified via pseudonyms.

**Research Design**

The original study incorporated a mixed-methods study design (Tashakkori & Teddlie, 2003). The study addressed the development of TCs’ digital competencies in a science methods course in which the assignments incorporated the integration of digital literacies on a variety of levels as TCs developed scientific timelines; concept presentations in science; and science resource websites, incorporating Prezi, Movie Maker, digital storytelling, simulations, DVGs, virtual laboratories, media, etc. Data sources for the study included questionnaires (views of, experiences with, and attitudes towards technology; and development of the digital scientific timeline and websites); TCs reflections on the biology timeline and website activity; recorded, semi-structured interviews about TCs’ views of the role of digital literacies in science education; and student work. Due to multiple research tools used for data collection, data triangulation is achieved. Therefore, ensuing discussion and analysis focused on highly reliable and valid data since the research tools effectively garnered both quantitative (surveys) and qualitative (surveys, reflections, interviews, coursework) information from the TCs.
Participants

The participants were TCs enrolled in the senior science/biology/physics/chemistry methods course in science education. Fourteen science education students (12 females, 2 males), ranging from ages 20-23 participated in this study.

Data Sources

Participants were required to (i) complete a questionnaire (approximately 20 minutes) on their views of, experiences with, and attitudes towards technology in education at the beginning of the course, (ii) complete a quantitative/qualitative questionnaire (approximately 20 minutes) reflecting on developing a scientific timeline and assessment strategies at the end of the course, and (iii) complete an open-ended survey (20 minutes) focusing on questions related to concept presentations and developing a science resource website. Additionally, volunteers were interviewed at the end of the course, for a duration of approximately 30 minutes, about their views of the role of digital literacies in science education. TCs’ course work also comprised the data set.

Data Analysis

As a whole, secondary data (in the forms of questionnaires and surveys, reflections, interviews, and coursework) examined the TCs’ relationship (feelings, beliefs, attitudes, etc.) with the digital timeline assignment to observe how it affected their teacher-education experience. As well, it clarified their inquiry with the forms of technology used in both their assignment and their course, their technological and digital literacy demonstrated throughout their experience, and their overall perception of digital technology as a broader concept that affected their day-to-day practice as future teachers. Quantitative data (questionnaires and surveys) were imported and processed in Microsoft Excel and analyzed using descriptive
statistics and inferential statistics. Qualitative data (reflections, interviews, and coursework) were analyzed through an interpretational analysis framework executed through the process of thematic coding and constant comparative method (Stake, 2000) using NVivo 12 software to address the goals of the study.

Seven of the fourteen teacher candidates who completed the surveys volunteered to be interviewed at the conclusion of their course. Table 1 lists the TCs’ pseudonyms, their subject specialties, the grade levels they were eligible to teach, and a brief list of any notable digital programs, applications, software, or other technologies they were familiar with or discussed during their interviews.

*Table 1. Teacher candidate profiles.*

<table>
<thead>
<tr>
<th>Teacher Candidate Pseudonym</th>
<th>Subject Specialty</th>
<th>Grade Levels</th>
<th>Digital Technologies Referenced/Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mae</td>
<td>Physical Education, Biology</td>
<td>7 - 12</td>
<td>Tiki-Toki, SpongeLab Interactive</td>
</tr>
<tr>
<td>Raquel</td>
<td>Science (General), Biology</td>
<td>7 - 12</td>
<td>PowerPoint, Prezi</td>
</tr>
<tr>
<td>Gurpreet</td>
<td>Biology, Science (General)</td>
<td>7 - 12</td>
<td>TimeToast, Moodle, SpongeLab Interactive</td>
</tr>
<tr>
<td>Nina</td>
<td>Science (General), Biology</td>
<td>7 - 12</td>
<td>Prezi, PowerPoint,</td>
</tr>
<tr>
<td>Alanna</td>
<td>Kinesiology, Biology</td>
<td>7 - 12</td>
<td>PowerPoint, Moodle, SpongeLab Interactive, DVGs</td>
</tr>
<tr>
<td>Giulia</td>
<td>Mathematics, Science (General)</td>
<td>7 - 12</td>
<td>PowerPoint, Smart Notebook, TimeToast</td>
</tr>
<tr>
<td>Marni</td>
<td>Dance, Science (General)</td>
<td>7 - 12</td>
<td>Gizmos, Facebook, Moodle, Prezi</td>
</tr>
</tbody>
</table>

In the interviews, TCs participated in conversations on numerous topics, namely centered on digital literacies, digital competencies, and their experiences with creating digital timelines. Below are sample interview questions (Appendix D: Developing Teacher Candidates’ Digital Competencies).
1. Briefly describe your understanding of digital literacies.

2. Have you experienced/implemented digital literacies in coursework and/or teaching prior to this science methods course? Explain.

3. Do you feel that digital literacies should be incorporated in all levels of science teaching? Why? How should they be incorporated?

4. What are the benefits of incorporating digital literacies as perceived by (a) students and (b) teachers?

5. a. What are perceived drawbacks/obstacles to implementing digital literacies with students? How can these be addressed?

   b. What are potential obstacles to implementing digital literacies in the classroom? How can these be overcome?

As responses, in some cases, were detailed, intricate, and unique for each TC, the data was coded using NVivo 12 to draw upon thematic similarities between TCs’ responses for the purpose of addressing themes of this research and providing analysis in the latter portions of this thesis. In reporting interview data, interview questions are categorized as headings that described the point of inquiry or focus that each question addressed.

By communicating the patterns and findings of the collected data, it was analyzed and, subsequently, discussed to see how it addressed not just the research questions, but how it related to digital competencies as a more holistic concept. The data was used to explore TCs’ experiences as a form of personalized learning since the TCs had a fair degree of autonomy and creative freedom to design their digital timelines. As well, their experiences in creating the digital timeline informed how personally engaged they were during the assignment and their course, which could be reflected in future pedagogical and curricular choices they may undertake to reflect and foster classroom engagement in their own practices. TCs’ experience with familiar and new technological devices, equipment, and software during the creation of their digital
timelines inevitably provided information to form inferences and conclusions about what decisions TCs made related to technological integration in the classroom.

Depending on what the data indicate (for example, whether or not their experiences affected their attitudes, competency, and affinity towards certain devices and applications), it may dictate if TCs are more open, averse, or neutral to new and familiar forms of digital technology. In the case of this research, it could indicate where, for instance, the use of non-mainstream digital literacies like DVGs or timelines may be integrated in the classroom in the future, based on how straightforward and successful the TCs’ experiences are with creating digital timelines (DeCoito, 2014). Of course, there are numerous other opportunities that could potentially emerge from working with this data that will allow for valuable and meaningful connections to be made to the research interests that are prevalent throughout this thesis.

**Diagnostic Lexical Analyses**

Using NVivo 12, a series of word graphics were rendered to draw upon themes that emerged from TCs’ interviews. To ensure the validity and reliability of frequently used words across each graphic, coded statements were manually assessed to verify if words were used in appropriate contexts and not as filler words (e.g., “I think that...”; “this feels like...” etc.).

**Across the entirety of TCs’ interviews.** In recognizing that interviews would touch upon this study’s focus in some capacity, a diagnostic measure was taken to associate terms and vernacular to these potential, anticipated themes (i.e., personalized learning, engagement, etc.) that would be identified in the latter portions of this thesis. A word cloud was generated to gauge what specific selection of words and terms were most commonly used in the collective total of the TCs’ interviews. Figure 1 highlights the most common words (and stemmed words).
Words that assumed attention were *think*, *like*, *digital*, *learning*, *using*, and *students*. Closer inspection revealed that other words, such as *timeline*, *assignments*, *science*, *know*, *different*, *teacher*, and *make*, were also used throughout the interviews. Many of these words, specifically *think*, *learning*, and *using*, could have been viewed as apparent indications of ongoing activity in the TCs’ classrooms, suggesting that engagement and active learning were emergent concepts.

The words *different*, *digital*, *incorporate*, *timeline*, *assignments*, and *make* could have been pertaining to teaching and learning, and the personalized, differentiated, and digitally influenced experiences that may have occurred for TCs and their students. The periphery words, such as *gaming*, *website*, *applications*, and *online*, could be interpreted as terms that provided a potential glance into broader study foci such as digital literacy, digital technology, and digital timelines, all of which would have been discussed predominantly during the TCs’ practicums.

**Across statements coded as “Personalized Learning”**. Figure 2 illustrates a word cloud highlighting the most commonly used words across TCs’ interviews that were coded as “Personalized Learning”.
Figure 2. Most frequently used words for statements coded as “Personalized Learning”.

In this graphic, there are four main words that draw attention: students, think, digital, and format. While student is not a particularly surprising word as most processes of personalized learning are presumably driven by personal goals and needs of any individual student, it is telling to see the words digital and format being used frequently by each TC. To elaborate, observing these words suggest that TCs’ view of personalized learning is dependent on the selection of very particular formats related to teaching, learning, and pedagogy. At the same time, it may also suggest that digital formatting is viewed as a popular, preferred, or recommended format to assist in instruction.

Another prominent word to highlight is timeline. The relevance of the word can be directly traced to the TCs’ assignment of creating their digital timelines. By seeing this word appear as frequently as it does, it alludes to the notion that the timeline assignment embodied aspects of or provided opportunities to engage with personalized learning.

Quite interestingly, words such as teaching, and teacher appear to be periphery words and are not mentioned as frequently as the previously discussed words in this theme. This may call
into question the role of the teacher in fostering personalized learning. Low frequency may indicate that TCs felt that teachers are more passive and less influential in classrooms geared towards promoting personalized learning than they would normally be in more traditional classroom settings. Based on this observation, it may signal that in personalized learning environments, teachers transition from their typical roles of transferring knowledge into more facilitative roles where they assist or guide technology-driven student learning.

**Across statements coded as “Achievement”**. In Figure 3, the most frequent words used by TCs in statements that were coded as “Achievement” are highlighted.

![Word Cloud](image.png)

*Figure 3. Most frequently used words for statements coded as “Achievement”.*

Unlike Figure 2, it is quite unclear to decipher or interpret what any of the most commonly spoken words may infer to newer meanings. Nevertheless, words such as students, digital, know, and think are important to consider in the context of achievement because they may reinforce what TCs believe to be central to achievement. Interview data may confirm that TCs view the relationship between students and digital technology as being the core of what defines achievement in schooling. Much like personalized learning, it suggests that student achievement
may be perceived to be impacted by the presence of digital literacies and digital tools and applications.

Other words to take note of include obstacles, literacies, technology, different, and classrooms. In the context of student achievement and achievement outcomes, these words are evidence of discussion centered on the potential difficulties of digital technology in classrooms and how student achievement in traditional classrooms may differentiate from student achievement in classrooms that cater to digital literacies and digital technology.

**Across statements coded as “Engagement”.** Figure 4 features the most commonly mentioned words for TCs’ statements coded as “Engagement”.

![Figure 4. Most frequently used words for statements coded as “Engagement”](image)

In particular, the word think is the most prominent word that appears in Figure 4. From the onset, it allows the assumption to be made that TCs’ highlight a potential connection between thinking and engagement, whether these assumptions entail that active thinking processes are examples of engagement, or classroom engagement may be a vehicle for promoting active thinking in students.
Another word to focus on is the word *like* as it presents many meanings to consider in the context of the interviews. Just as it was identified earlier that *like* could be used to signal comparisons, it may also have been used to illustrate preference or favour. For example, through engagement, students or TCs may have found that they “liked” to use certain digital technologies because they fostered engagement. Likewise, due to engaging aspects, TCs or students may “like” certain subjects and disciplines, such as science. Considering that the words *digital* and *timeline* were used quite frequently in interviews, it may suggest that the TC’s assignment was an influential factor in fostering engagement, be it through the process of creating them, or the process of presenting and sharing them among peers.

**“Motivation” word tree.** Although “motivation” itself was not a central focus indicated in the study questions, it is still pertinent to explore how many of the foci, such as achievement, engagement, and personalized learning, may have been impacted by motivation. In doing so, a word tree was generated in NVivo 12 to determine where, and in which contexts, motivation may have been used in TCs’ interviews (Figure 5).

*Figure 5.* “Motivation” word tree generated from TCs’ interviews.

In Figure 5, motivation is central to a few statements that provide rich meaning to understanding the contexts in which the term was used. Many statements are illustrated in this graphic, such as “digital applications enhance your motivation and engagement …”, “digital applications
enhance your motivation to construct a biology [timeline] ...”, and “[the timeline] assignment affect(s) the student’s motivation …”. These statements demonstrate that TCs recognized that learning and subject content can be linked to digital technology when motivation is indicated.

Statements such as “digital applications enhance your motivation to construct a biology [timeline]” can be interpreted in a way that suggest TCs believe that the digital tools around them, and in their classrooms are beneficial towards not only learning, but assignments and tasks at hand. Similarly, a statement such as “[the timeline] assignment affect(s) the student’s motivation and engagement ...” signifies that the TCs’ experiences of creating digital timelines are evidence of how engagement is impacted by technology and that the motivation stems from the assignments themselves. It alludes to a potential relationship where the format of assignments and the tools used to assist in completing them can potentially garner the interest of students and present them with value to obtain from their coursework.
Findings

In this section, findings from each of the data sources are presented. To recall, the study addressed the following questions:

1. Does employing digital technologies impact teacher candidates' (TCs’):
   a) personal engagement (i.e., subject content, digital devices, digital applications)
   b) personal achievement (i.e., statistical outcomes, learning processes, goals)?
   c) attitudes towards digital technology?
   d) ability to personalize learning?

2. If so, how are the impact(s) manifested?

In the following sections, findings are reported and elaborated upon, with the aim of addressing the research questions.

Surveys and Questionnaires

Digital Timeline Assessment

This questionnaire sought to understand the TCs’ views of, experiences with, and attitudes towards digital technology prior to beginning their science methods course and creating their digital timelines.

Digital timelines had been a concept that only 50% of students indicated that they had heard of prior to the course, however, this did not pose an issue as 92% of TCs indicated that they were provided an appropriate introduction to the concept and subsequent instruction about how to use them. This prompted TCs to discuss the level of support they received, indicating that support for both the (i) introduction of digital timelines and (ii) duration of making the digital timelines was adequate. Subsequently, TCs were asked about their use of effective strategies in terms of presenting coursework and ideas; representing growth over the duration of
their course; and development of learning. For all three questions, TCs believed they possessed strategies to address the different learning scenarios in their course. The questionnaire transitioned into asking students about the importance of several features in science teacher education courses. Figure 6 demonstrates the importance of eight different features in a science classroom, according to TCs (n=14).

![Figure 6. Common features of science teacher education courses as reported by TCs.](image)

Results indicate that specific features of a science teacher education course, generally, share a high degree of importance among TCs. Figure 6 indicates that coursework accessibility in one location, accessibility to teacher feedback, and opportunities to demonstrate examples of growth and development to potential employers are among the most prioritized and important features that should be incorporated in a science teacher education course. Peer involvement is assessed to be slightly less prioritized among this sample of TCs, given the opportunity to share
classroom experiences with peers, as well as the opportunity to work in learning communities with peers have lower averages of importance.

TCs (n=14) were asked a series of questions pertaining to the instructor involvement in their science methods course. Figure 7 demonstrates the mean frequency of the instructor’s involvement in the course, ranked on a scale from 1 – 4.

![Bar chart showing instructor involvement](image)

**Figure 7.** Instructor involvement in the science methods course, as reported by TCs.

TCs believed their instructor was highly involved in all items, except for two that were averaged to be slightly lower than the remaining items. It can be inferred that TCs felt their instructor was most involved in items related to learning and assessment. Questionnaire data indicates that the instructor was most involved in thinking about ways in which students could demonstrate evidentiary learning. This is substantiated by responses to questions centered on production of learning evidence, the active presence of valid and reliable evidence of learning from the students, the process of fostering assessment information geared toward fine-tuning
instruction and the learning environment, and the involvement of students in ongoing assessments of learning. While still assessed to be frequent, TCs indicated less involvement from the instructor in terms of summarization of learning, as well as the demonstration of learning from models that were composed of collected samples from the class.

In the next section of the questionnaire, TCs (n=14) were asked to agree or disagree with a series of statements about learning and assessment. In total, they were presented with twelve items and were asked to respond to how frequently they exhibited the items on the list. Figure 8 demonstrates the mean frequency, ranked on a scale from 1 (not at all) - 3 (all/most of the time).

![Figure 8](image.png)

**Figure 8.** TCs’ accounts of learning and assessment in the science methods course.

Graphical data indicates that TCs believed they could demonstrate numerous instances of learning and assessment throughout the duration of their course. While great disparity does not
exist in the TCs’ responses, there are a few items, in comparison to the remainder of the items, that are higher or lower than the average (~2.75/3). Both the statement about collecting and referring to samples, as well as the statement pertaining to collecting evidence of the TC’s own learning, are ranked more frequently among the TCs. The item that is ranked proportionally lower out of this series of questions is related to debriefing and learning with peers in their class. This is consistent with TCs’ responses (Figure 6), as they indicated that opportunities to share experiences and learn in a community with peers were not seen as the most important features of a science teacher education course.

Technology Usage Survey

The TCs were administered a survey that explored their usage of technology. Opening questions asked TCs how often they accessed online course material. Responses indicate that TCs were accessing resources at an average frequency of just over one time per day. In comparison, when asked about how often they used technological resources, like their university computer labs, TC responses indicate that they were only using their on-site technological resources at around a rate of 1-3 times per month.

TCs (n=14) were presented with a list of technological devices and were asked to rank which devices they owned and which devices they would like to own. Table 2 illustrates TCs choices.

Table 2. TCs’ list of devices owned and desired.

<table>
<thead>
<tr>
<th>Device</th>
<th>Own (%)</th>
<th>Would like (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netbook</td>
<td>14.29</td>
<td>14</td>
</tr>
<tr>
<td>Global Positioning System (GPS)</td>
<td>43</td>
<td>29</td>
</tr>
</tbody>
</table>
As a follow up to this question, TCs (n=14) were asked to indicate how willing they would be to maintain monthly charges pertaining to this list of devices. On a scale from 1 (less than $20) and 6 (more than $100), the average among TCs was 2.85/6, meaning that TCs were willing to spend just over $20-$39 and just under $40-$59 per month.

Another set of questions sought to understand how frequent TCs (n=14) used their devices to create or use digital functions on a weekly basis. Figure 9 displays a list of five different applications and the individual use of each application over the course of a week.

![Figure 9](Image)

*Figure 9.* TCs’ frequency of digital applications usage.
The data suggests that TCs were seldom engaging in any of the listed digital applications with the exception of uploading photos, with the total participant sample uploading between 1 and 5 times per week.

In terms of courses, TCs (n=14) were asked to identify, on a scale from 1 (none at all) to 4 (more than 10), the number of courses they were enrolled in that involved the use of online educational technology. Along the participant sample size, the data was equally distributed (Figure 10).

![Figure 10. Online educational technology in course delivery as reported by TCs](image)

Findings indicate that TCs (11 out of 14 participants) had been enrolled in courses that involved the use of online educational technology or contained an online educational component.

TCs (n=14) were asked a series of questions pertaining to preferences of course design, which included technology supplemented courses, hybrid courses, and fully online courses. The average preferences for all three types of courses was moderate among the TCs, perhaps suggesting that their course preference was not heavily influenced by the amount of technology present in the delivery of the course. These questions enabled TCs to answer a new series of questions surrounding the usefulness of certain technological materials in the classroom, such as audio-only captures, audio plus projected material captures, and audio plus projected material
captures with video of the instructor. Not surprisingly, there was steady progression in perceived usefulness as TCs felt the options with more components were more useful to their education than the options with less technological components. The survey transitioned to questions that asked TCs to rank their level of agreement on a scale from 1 (strongly disagree) - 4 (strongly agree). Figure 11 highlights TCs’ preference for educational technologies.

![Figure 11. TCs views of educational technologies in the science education course.](image)

TCs’ attitudes towards and opinions of educational technologies were garnered from their responses. By addressing the statements that are ranked to have lower agreement among TCs, it is evident that educational technology did not correlate with more work demand, nor higher
quality work in their course. At the same time, educational technology did not diminish the role of the instructor or alter the structure of the class as TCs did not feel their course was more student-centered. On the other hand, statements that indicate high collective agreement illustrate that educational technology has (i) been advantageous for the work of TCs, and (ii) assisted TCs in succeeding in course work. Although not to the same extent as the aforementioned statements, the statement about most available educational technologies being easy to learn shared moderately strong consensus among TCs. Their responses to questions in Figure 11 are supplemented in the next series of questions centered around course preferences with different levels of educational technology. Figure 12 highlights TCs’ preferences.

*Figure 12.* Preference of educational technology usage in courses (%), as reported by TCs.

Findings highlighted in Figure 12 are congruent with Figure 11. Based on the percentages in Figure 12, it is conclusive that TCs (n=14) have significant preferences for courses with
moderate and large amounts of education technology usage, while noting that exclusive technology usage is not favourable.

TCs (n=14) were asked to rank the usefulness of a list of technological items. Figure 13 illustrates the perceived usefulness of each item.

Figure 13. Usefulness of technological tools as reported by TCs.

Findings indicate that the most useful technological items in the course, as reported by TCs, included instructor notes and slides, a university class website, an email system to share and submit coursework, and visualization tools that assist in the learning of new concepts. Technological items such as blogging tools are ranked to be comparatively less useful, which is not alarming, as TCs indicated that they had little to no experience creating and maintaining blogs (Figure 13).

TCs (n=14) were asked to rank their degree of comfort with a series of digital and technological items, on a scale from 1-4. Findings are displayed in Figure 14.
Figure 14. TCs’ comfort level with digital and technological resources.

Figure 14 demonstrates that TCs have a higher level of comfort with digital and technological resources that are more conventional in modern classroom practices, such as Google Docs (for written assignments) and online quizzes (for testing/examination) as opposed to more nuanced and atypical uses (e.g., creating animations with programs, using desktop publishing programs, etc.).
Finally, TCs (n=14) responded to a series of questions related to the degree of problems that certain technologies posed for them during their course. TCs were asked to rank them on a scale of 1 (large problems) - 4 (not a problem). The results are displayed in Figure 15.

![Bar chart showing the degree of problems posed by different technologies]

Figure 15. TCs reported problems with digital technologies.

In general, the TCs did not encounter major problems related to technology usage in their course. In Figure 15, none of the items posed problems that were deemed to be in excess of small or moderate. The highest ranked problems are related to network and the Internet, and the amount of time needed to learn how to use educational technologies.

**Scientific Timeline Reflection**

As part of the data set, TCs (n=14) completed a survey exploring their experiences with the digital timeline assignment centered on the history of science. All questions included a 5-point Likert scale (1 (Strongly disagree) – 5 (Strongly agree)). Questions were categorized into two sections: Technological Literacy, where a majority of the questions focused on TCs’ knowledge, competence, and learning processes of technology; and Reflective Learning, whereby questions focused on TCs’ feelings, attitudes, and experiences with learning and using technology.
**Technological Literacy.** TCs (n=14) were asked about their experience with certain aspects of their digital timeline, during the process of creating them. The questions and subsequent responses are illustrated in Figure 16.

![Figure 16](image)

Figure 16. TCs’ development of technological literacy.

While TCs collectively displayed a strong sense of agreement regarding learning about technology, new equipment, and new software, it is not as unanimous in terms of newfound learning affecting how frequent or how interested they would be in incorporating technology in their practice in the future. It is also worth noting that the process of creating digital timelines did not necessarily pose problems or issues to TCs, as their responses suggest that they were unaffected or indifferent towards difficulties related to equipment, software, and prior lack of knowledge.

**Reflective Learning.** TCs (n=14) were asked to rank a series of statements related to reflective learning about their digital timeline. Findings are illustrated below in Table 3.
Table 3. TCs’ account of reflective learning pertaining to scientific timelines.

<table>
<thead>
<tr>
<th>Statements of Reflective Learning (Scientific Timeline)</th>
<th>Frequency (Mean) [1–5] n=14</th>
</tr>
</thead>
<tbody>
<tr>
<td>While creating my biology timeline I learned to organize and present ideas.</td>
<td>4.077</td>
</tr>
<tr>
<td>While creating my biology timeline I learned to apply technology in my learning.</td>
<td>3.786</td>
</tr>
<tr>
<td>While creating my biology timeline I learned to evaluate my learning.</td>
<td>3.643</td>
</tr>
<tr>
<td>Digital biology timelines are more powerful and convenient than traditional poster formats.</td>
<td>4.429</td>
</tr>
<tr>
<td>Biology timelines can showcase learning</td>
<td>4.143</td>
</tr>
<tr>
<td>Biology timelines provide a means of self evaluation.</td>
<td>3.692</td>
</tr>
<tr>
<td>I can apply what I learned from creating a biology timeline to my learning.</td>
<td>4</td>
</tr>
<tr>
<td>I felt time constraints when creating my biology timeline.</td>
<td>3.143</td>
</tr>
<tr>
<td>My biology timeline was not too limited in the topics that were covered.</td>
<td>2.643</td>
</tr>
<tr>
<td>It was not challenging to select the content of my biology timeline</td>
<td>3.214</td>
</tr>
<tr>
<td>I was able to include a sufficient number of topics in my biology timeline.</td>
<td>3.5</td>
</tr>
<tr>
<td>I was able to be creative in my timeline.</td>
<td>4</td>
</tr>
<tr>
<td>I did an adequate amount of reflection on my development as a learner during the timeline.</td>
<td>3.286</td>
</tr>
<tr>
<td>There were sufficient opportunities to receive feedback on my timeline from my peers.</td>
<td>3.5</td>
</tr>
<tr>
<td>I found the biology timeline assignment to be collaborative.</td>
<td>3.714</td>
</tr>
<tr>
<td>I found the biology timeline assignment to be inclusive.</td>
<td>3.643</td>
</tr>
<tr>
<td>I found the biology timeline assignment to be dynamic.</td>
<td>3.5</td>
</tr>
<tr>
<td>I found the biology timeline assignment to be inquiring.</td>
<td>3.786</td>
</tr>
<tr>
<td>I found the biology timeline assignment to be reflective.</td>
<td>3.286</td>
</tr>
</tbody>
</table>

Table 3 demonstrates that TCs exemplified strong collective agreement for many of the statements and questions about reflective learning. The main finding pertains to the
effectiveness of digital timelines versus traditional, text-based posters (4.429/5), with many TCs agreeing that digital timelines were more effective. Other statements that rendered high agreement among the TCs included the facilitation of creativity (4/5), showcasing of learning (4.143/5), and application of learning (4/5). Many of the terms that TCs were asked to assess in relation to their timelines (e.g., creative, collaborative, etc.) were also deemed to be terms that TCs felt they could accurately use to describe their digital timelines.

The remaining questions pertained to more general aspects of TCs’ experiences, such as level of guidance required versus level of guidance provided, time allocated to work on the project, and other aspects of the assignment (Table 4).

*Table 4.* TCs’ general statements about digital biology timelines.

<table>
<thead>
<tr>
<th>General Statements (Digital Timeline)</th>
<th>Frequency (Mean) [1 –5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>This assignment needs to have more direct guidance throughout the process.</td>
<td>3.143</td>
</tr>
<tr>
<td>Sufficient class time was allotted for working on my timeline.</td>
<td>3.357</td>
</tr>
<tr>
<td>I had adequate access to equipment when creating my biology timeline.</td>
<td>3.786</td>
</tr>
<tr>
<td>My biology timeline looks professional.</td>
<td>3.857</td>
</tr>
<tr>
<td>Guidelines for the biology timeline assignment were clearly stated.</td>
<td>3.5</td>
</tr>
<tr>
<td>There were sufficient opportunities to receive feedback on my timeline from my instructor.</td>
<td>3.786</td>
</tr>
<tr>
<td>There were sufficient opportunities to view my peers’ timeline during the process.</td>
<td>3.429</td>
</tr>
<tr>
<td>The biology timeline assignment should be optional.</td>
<td>3</td>
</tr>
<tr>
<td>I had adequate access to needed software when creating my biology timeline</td>
<td>3.857</td>
</tr>
<tr>
<td>I had adequate access to needed equipment when creating my biology timeline.</td>
<td>3.857</td>
</tr>
<tr>
<td>I would like to publish my biology timeline on the web</td>
<td>2.929</td>
</tr>
<tr>
<td>I plan to use my biology timeline in job searches.</td>
<td>2.714</td>
</tr>
<tr>
<td>I do not plan to use my biology timeline in the</td>
<td>2.923</td>
</tr>
</tbody>
</table>
I had adequate access to technical support when creating my biology timeline. 3.5

As a whole, most responses tended to hover over the mark of neither disagree nor agree (3/5). However, three statements fell under this mark of indifference, all of which pertain to the usage and value of the digital timeline outside of their science methods course. Findings indicate that TCs potentially do not see the value or opportunity in incorporating their digital timeline in their job searches or on the web to share publicly, despite indicating their belief that their digital timelines looked professional.

In sum, across three surveys, there was much to unpack pertaining to TCs’ attitudes towards, experiences with, and reflective thoughts of digital technology and their digital timeline assignment. Notably, what can be inferred is that where TCs indicate positive feelings toward digital technology in their lives, their preference leaned toward engaging with familiar and mainstream digital technology and technological uses. Nevertheless, even though they maintain these preferences, quantitative data also indicate that TCs’ engagement with newer or unfamiliar digital technology (i.e., creating digital timelines) was not met with aversion, presumably since data indicates that TCs felt they were granted adequate access to appropriate equipment or technology they needed, in addition to being adequately supported by their instructor throughout the duration of their course.

Interviews

While survey data was helpful in quantifying data related to TCs’ attitudes and competence using digital technology and devices, it is relevant to explore the experiences of TCs from a lens that will leverage qualitative data to address the research questions and support the goals of this
research. Importantly, in this section, TCs’ recollections may act as a way to substantiate and qualify the speculated themes and ideas that were identified in the series of word graphics (see Data Analysis).

**Individual understandings of digital literacies**

At the onset of the interview, TCs were asked to share their understanding of digital literacies. Generally, many of the TCs associated digital literacy with aspects like familiarity and fluency with digital devices, software, and applications. As well, a few highlighted its potential as a resource to aid educators and students. Alanna explained her conception of digital literacies, stating,

> I think of digital literacies as anything either computer based or something that is interactive and hands-on that students are using to better their knowledge on particular topics and things that make it more interesting for them. So, it’s not just teacher lecturing, it’s more of using other media devices to get students engaged in different topics.

Gurpreet believed the world was becoming a “digitalized culture” and that incorporating digital literacies was necessary for students to “understand how the world connects with each other”, which was similar to what Raquel understood digital literacies to be, which was a process of understanding how digital technology evolves and how human beings are able to adapt to those changes.

Additionally, Marni viewed digital literacy as part of a set of basic skills for students to possess in their lives. Mae added that digital literacies referred to the ability to “navigate technological things”, such as computers and smartphones, and Nina believed digital literacies entailed “understanding digital media and software programs”. Looking at it through a different
lens, Giulia interpreted digital literacies as “using technology with teaching” through the use of videos, as well as audio technology.

Experiences with digital literacies in coursework and teaching practice

TCs were asked to expand on the previous question by providing examples and lived experiences of when they interacted with or used digital literacies in their life, whether as students or in their teaching practicums. While TCs had been familiar with some presentation-based programs like Prezi and PowerPoint, and also had familiarity with certain social media, there were discrepancies in how frequent the experiences with using digital literacies were for each TC in the context of schooling.

For example, both Marni and Mae had no particular experiences with using digital literacies as students, much less as teachers. In Mae’s case, she explained, “I [taught] Phys. Ed. Phys. Ed. was my other teachable, so we were always in the gym. Like, throwing stuff and just playing”.

Gurpreet had a lot of experience as a student using digital literacies, referencing her courses at university which used Moodle (learning management system) and many of her assignments that involved presentation-based technologies, but acknowledged that she was yet to engage with digital literacies as a teacher in her practicum. Likewise, Giulia had experience using Smart Notebook and PowerPoint as a student but was unable to incorporate digital literacies when she was teaching mathematics in her practicum.

On the other hand, Nina was one TC who had some experience with using digital literacies as an educator. She discussed an assignment that she administered to one of her classes in her practicum, explaining,
I have asked my students to do [something] like a collage. A digital collage, I guess you could say ... I think it was in my grade 10 course. I do not remember the specific assignment, but I asked them to come up with a collage of different pictures.

Alanna also found the opportunity to use digital literacies in her teaching practicum through the use of digital video games as learning activities. She discussed,

The school that I was at, they actually had laptops, a class set, so I would do a lot of online activities. Sponge Lab was really useful ... The day that I taught that I would have them go on and do two of the games. The Krebs Cycle game and the Electron Transport Chain game and I actually saw that they improved their learning a lot quicker than simply just me standing at the front of the classroom lecturing on it.

**Should digital literacies be incorporated in all levels of science teaching?**

Quite unanimously, the TCs believed that digital literacies were almost necessary for teaching science across different levels. For example, Raquel believed that positioning digital literacies in technology was necessary as she believed that real-world applications of science were rooted in digital technology. In terms of using digital literacies as a pedagogical tool, she explained that simple tasks, such as creating an online poll to review learning at the conclusion of a lesson, are everyday methods of being able to incorporate digital literacies into practice. As well, Gurpreet felt that science was becoming a “kind of [a] digital discipline”. She explained her rationale,

Because, especially with biology, there are a lot of concepts about structure, for example, like proteins and stuff, there are different structures. So, having digital representations of what it would look like instead of just describing it, is beneficial.
Mae and Nina both felt that incorporating digital literacies into practice was important because it would foster engagement in students. Specifically, Nina stated,

I think [digital literacies] should [be incorporated] because it’s very engaging, and kids nowadays are always on the computer anyway, and so I think that’s a way to engage them and get them in and get them ready.

She later explained that she would have her students use presentation-based tools, such as Prezi and PowerPoint, as a task to develop creative presentations to help promote interest in science to students who may have been bored and uninterested in the subject.

Giulia believed that starting students with digital literacies at a young age is precisely why digital literacies should be incorporated at all levels. She shared an experience about working with kindergartners and the successful facilitation of storytelling through the use of a Smart Notebook, discussing that the children enjoyed the interaction and were eager to learn about the story as a result of the digital technology showcasing engaging aspects, such as colours and animation.

**Benefits of digital literacies perceived by students and teachers**

After having had an opportunity to explain why digital literacies should be integrated into all levels of science education, TCs were asked to expand on their thoughts by listing any of the potential benefits that existed for students and teachers.

Alanna maintained that the presence of digital literacies kept students and teachers up to date and impacted them throughout their life. She explained,

I think that so much of this world that we are in today is all about technology, and so, if students are not learning about technology, they are not really keeping up, so as teachers we have to adapt our teaching techniques to what’s going on in the world as well.
She continued by discussing how she was taught how to use PowerPoint and mentioned,

I actually use that [PowerPoint] now in my teaching and I used it for my block and it helped me stay more organized, so as students, you are learning to make your life easier

... if we can teach our students how to do that, it will be beneficial for them for whatever they have going on in their life.

In closing she added,

We can post everything that we have done in class, and we can also see what other students have done and we can save those on USBs and have them forever in our teaching careers.

Additionally, Marni felt that digital literacies would alter the perception of schooling for students, arguing that they may have seen their schools as “cool” or more engaging because of all the new digital technologies available. She argued that for teachers, digital literacies could connect teachers and students together to shift the classroom experience. She described an experience in the computer lab at her practicum, stating,

My mentor teacher installed a software where he could monitor all the computers and ask students questions and actually have chats with them which I found helped her students who were really embarrassed that they might not have known something [about the lesson]. So, it’s really nice that, right then and there in the classroom, you can interact with students, as well as overview what’s going on and keep track of the ones who are on YouTube all day and block them completely. So organizationally, it is actually quite great, because once you set something up, you have all the assignments there, and all the submissions there.
Marni also believed that digital technology could be beneficial for students as it could contribute to simplifying learning for a larger classroom of learners. She shared an example of how her mentor teacher approached teaching their class about using Microsoft Excel spreadsheets. The teacher had instructed students to seek out videos, audio files, and PDF documents, among other resources, as a way to learn how to use the program. By doing so, students were afforded freedom to learn from resources that appealed to them and could engage them, and there was less pressure on the teacher to exact the learning for the students.

A few TCs believed digital literacies benefitted teachers because they contributed to easing the workload and rigours of the teaching practice, especially challenges related to sharing knowledge and fostering understanding of subject content. Giulia talked about the role of digital technology to supplement understanding and reinforce knowledge. She explained,

The hard part of teaching is basically when the students do not really understand what you are saying, and I think that technology really helps out [to clarify understanding].

Gurpreet shared similar sentiments related to the point made by Giulia. Gurpreet explained that in some scenarios, showing a short video about a certain concept to the class may have been more effective than her trying to explain the concept verbally. Raquel furthered this notion by stating that using certain digital technologies could decrease the amount of time spent on preparation for teachers, implying that teachers could allocate their time and effort elsewhere.

Conversely, Nina felt that digital technology was an asset in the sense that teachers could use it to modify their lessons and assignments for the different groups of students they taught. She stated,

Well, teachers do not have to pen up or assign the same assignment year [after] year. It can vary depending on how you change your assignment. So, one year can be having
students work on a [Prezi], another one can be doing a storybook, that type of thing, so the teacher is always seeing something new, and that is exciting.

**Perceived drawbacks and obstacles of implementing digital literacies**

Although TCs shared a lot pertaining to the many ways that digital literacies could positively impact students and teachers, they were also asked to reflect on digital literacies and identify where potential issues and negative impacts could arise.

Giulia believed improper training could affect teachers. She stated, “Even if we have the technology in school, teachers wouldn’t use it effectively and properly, I think, because we weren’t really trained to do so”. To this, she discussed professional in-service training as a remedy to mitigate any mal effects.

Alanna raised a few concerns that could arise with the implementation of digital literacies. First, she pointed to the safety aspect of using digital literacies as a potential drawback for teachers and students. She discussed the broad landscape of the Internet and explained she was worried about students who were not careful as they could subject themselves to cyber-bullying or mistakenly access inappropriate websites. She suggested that teacher mediation, such as setting up a class forum or using learning forums like Moodle, could address these concerns. Additionally, she indicated that students would need to be aware of plagiarism when working with online technology as any potential failure to provide proper citations could result in copyright infringements and violating copyright laws.

In shifting the focus, Alanna also identified accessibility to digital technology as a concern for students and teachers, communicating that some students may not own, for example, computers at home. She stated that such a reality may mean that some students could be less digitally competent than others, and the disparity may lead to potential insecurity when working
with digital literacies at school. Gurpreet also felt that accessibility was an issue in terms of logistics, citing that some schools may have been lagging behind in terms of digital technologies present within their classrooms as opposed to other schools. Giulia also felt that limited resources in a school were an obstacle, however she looked at the issue from a financial lens, stating,

The challenge is the funding, I guess … there are some schools that are lucky enough to have laptops in their classrooms, so that is really beneficial. But if there are schools that [do not] have much … you [would have] to book the computer labs, and it is limited.

The lack of funding towards devices, tools, and resources was also seen as a drawback for Mae when asked to identify emergent obstacles.

While Marni shared similar thoughts about access to digital technology, and the need for new resources as an obstacle for teachers, she also possessed an entirely unrelated viewpoint on the drawbacks of digital literacies in the classroom. She stated that distractions from digital technology posed an obstacle that teachers should be aware of. She elaborated by stating,

I know I had to actually set up my lesson so that I would not have to do transitions between pieces of technology, because if I did that then they were instantly gone. I would not get them back. It would take about 20 minutes of me telling people to sit down, and go here and go there, before they would pay attention again. And that was just from a 30 second switch of pieces of technology I was using, because that is just how it was.

She suggested that the potential solution was to design lessons in a way that students could find themselves engaged with the content being taught, potentially leading to them unpacking value from the lesson. She also explained that, although teachers design how they structure their
lessons, there is still a personal responsibility for students to be accountable for their learning in the classroom.

Raquel briefly discussed distractions and accessibility as potential drawbacks but identified the liability of digital literacies as the major obstacle for teachers. She clarified,

If there is going to be something that goes wrong with your technology, you’re completely relying on whether or not it is going to work, so you would always have to be prepared with some sort of backup.

She stressed the need for preparation, such as having back-up plans that she mentioned, so as to address the scenario where digital technologies could be ineffective or fail.

*The Digital Timeline*

A significant portion of the interview was centered on the digital timelines that TCs created and are presented as sub-categories. These include: the application used, success achieving goals and outcomes, learnings from experience, comparisons between digital-based and paper-based timelines, motivation, and engagement.

**Application used.** TCs predominantly used familiar and popular presentation-based technologies to make their digital timelines, such as Prezi and PowerPoint. However, some TCs also used digital technologies that were specific and geared towards timelines, such as TimeToast and Tiki-Toki.

Raquel was one of the TCs who used Prezi because she believed it would be more dynamic than PowerPoint. At the same time, she acknowledged that she had not ever used Prezi before, so this was an opportunity to become familiar with the program. Likewise, Nina also built her digital timeline using Prezi because she had not ever used the program. She was inclined to use
Prezi because she believed that using the program would enable her to gain experience that could be transferable into her teaching practicum.

Like Nina and Raquel, Marni selected Prezi as the program to make her digital timeline. However, rather than selecting the program because she was unfamiliar or wanted to learn how to use it, she chose Prezi because of how user-friendly it was to share information. She elaborated,

I really liked the fact that you can link it up to websites and YouTube videos and get everything in there … music, and pictures and also from the fact that, in order to do it you have to put in the URL, so it’s instantly cited.

When prompted, she confirmed that the flexibility of the program was the major reason for choosing Prezi.

Alanna decided to use a familiar presentation-based program in PowerPoint to create her digital timeline. When she was asked about her rationale for selecting the program, she cited the simplicity of how easy it was to learn and use the program. She stated,

I thought that it was quite easy to use, for someone who is just looking at our PowerPoint and hasn’t used this application before. It’s quite straightforward. You click on a timeline and it goes to the year and it says what happened in that year, and there’s buttons on the page that you click on that bring you back to the original timeline page that can allow you to click on other years.

The remaining TCs used websites and programs that were specifically tailored for creating and maintaining digital timelines. TimeToast was one website that two TCs used to create their timelines. Gurpreet shared that she chose to use TimeToast because she was able to display her designated time period in a clear and organized manner. She commented,
I thought it was interesting because it actually showed the full 1700 to 1799 time period and then in between the years, there were events points, and if your [cursor] went over an event’s point, it would have a picture and also a short description, and you could expand that description if you clicked on it. So, I thought that was quite interesting because you had everything there in your birds-eye view and you can pick and choose to see which ones you want to see more of and learn more about.

Giulia also used TimeToast and noted similar sentiments as to why she decided to use the program. Giulia appreciated the software and its capabilities to pinpoint each event along the time grid because each plotted point on the grid could show multiple discoveries, which allowed for her timeline to be very detailed and informative while not being overly complicated to implement.

Finally, Mae used Tiki-Toki, another software specific for creating digital timelines. Much like other TCs with their respective digital timeline technologies, she selected the software because she found it was both user-friendly and easy to navigate.

**Success of achieving goals and outcomes.** Having had full autonomy to create digital timelines in their likeness, TCs were asked if they felt they were able to achieve any learning goals or outcomes through their work. Outcomes and goals may have included constructing knowledge, conveying understanding, and learning new knowledge, among other goals.

Marni responded by signalling that learning and gaining new knowledge was a successful outcome. She acknowledged that the process of creating a digital timeline taught her significantly about the contextualization of science throughout history in conjunction with different environmental aspects. She elaborated,

There was a social context for every point and that was really helpful because I find …
I didn’t realize it until I did the timeline, but history class timeline is separate from your science timeline which is separate from your English timeline which is separate from your social science timeline, so you don’t actually … you kind of forget when various things were going on, and when you see them all together, it kind of gives you a huge social context.

Raquel indicated that the presentation of the timeline itself was a successful outcome. She felt the class was engaged with her work because they had participated through asking a lot of questions about the timeline. As well, she also talked about the academic mark she received from her instructor as another positive outcome. Similarly, Nina felt that receiving feedback throughout the process of creating her timeline was a positive sign that she was working towards success. She also mentioned the level of understanding that was achieved by her peers as a successful outcome.

Both Alanna and Gurpreet had mixed feelings about their digital timelines in terms of successful outcomes. While Alanna was proud of her work, she had regretted not including more non-scientific events in her timeline, such as those related to politics, to have further contextualized the state of the environment and time period she was responsible for presenting. For Gurpreet, she felt that by the end of assignment, she had understood more about science and biology specifically. However, the process of creating the timeline was “chaotic” and “the whole construction of it was not as much fun as the completed assignment”.

Quite simply for Giulia, creating a thoroughly detailed digital timeline was a successful learning outcome. As well for Mae, she felt the ability to link text with pictures, videos and other media was effective in constructing knowledge and conveying understanding of her timeline.
**What was learned through the experiences?** As TCs had an opportunity to discuss what they felt was successful about their timelines, they were subsequently prompted to discuss what they learned about a series of topics, such as science, technology, and the nature of science.

*Science and Scientists.* Both Alanna and Giulia found themselves intrigued by the ever-changing and vast nature of science throughout history. Giulia stated, “the smallest things help others or help scientists to discover something even new … it leads to something better, I guess … I found that there were a lot more science discoveries than I would imagine”. Alanna was critical of the lack of diversity and representation in scientists, in particular the lack of women in historical contexts. However, she did acknowledge that science had become progressive over time with women gaining more of a voice and more recognition for their contributions as scientists over the years.

Mae indicated that before her assignment, she had little interest in science or scientists. However, one key realization for her was that she learned that scientists were not solely science-focused or existing in isolation; they were also just “regular people too”.

Marni provided an anecdotal account about what she learned about science and scientists in terms of real-world applicability. Having had Dance (Physical Education) and Science as specialized teaching subjects, she discussed a female scientist and their work towards developing shoes that were designed to be both comfortable and tailored for better athletic performance and how she was able to form salient connections to her teaching disciplines. She elaborated,

This [the scientist’s work with shoes] is the early beginnings of what we see in sports science and kinesiology and what we have started to get into in dance science, which is very recent, so it kind of helped me to realize that even something that seems mundane … there’s a thought process behind that.
She closed her statement by sharing that her experiences creating the digital timeline demonstrated that scientists were not individuals who always worked in “massive laboratories”; they simply saw problems and attempted to fix it, which “brings it back down to earth a bit, instead of making scientists seem like other worldly beings”.

Raquel, much like Alanna and Giulia, felt that she understood the extent of how often science was changing and advancing over periods of time. However, much like Alanna, she also commented on the diversity of scientists, stating, “They come from everywhere, males, females, all ages, that sort of thing”.

Nina was quite straight-forward and simply stated that she learned about the events of the discoveries and about the history, background, and lives of the scientists. Gurpreet also stated that it was “interesting to see the interpretations of certain people and scientists in general”.

**Technology.** TCs were asked to reflect on what they learned about technology in their digital timelines. Gurpreet reflected on what she learned about technology, simply stating that she enjoyed using TimeToast as it was fairly simple to use. As Gurpreet had been assigned the time period of 1990-1999 for her digital timeline, she did not note any advancements of the technology of her era, noting that science research “didn’t really use much technology, it was more theory”. This contrasted Mae’s account of what she learned about technology in her digital timeline. She stated,

I learned a little bit more about the science technologies. What was in my time period was about PCR [Polymerase chain reaction]. So, we learned the PCR technology and that kind of stuff, so that was cool.
Nina also felt she learned about the technology that was prominent in her designated time period, referring to the invention of the microscope, as well as any other technological tools that were invented or used during that time period.

Much like she noted about science, Alanna acknowledged the ever-changing landscape of modern technology, citing the examples of cellular phones and comparing their changes over time, from large and thick phones to much smaller and much thinner phones. Marni corroborated this notion, indicating she learned about the nature of technology and its tendency to change in “waves”, citing a similar example regarding the evolution of cellular phones.

Giulia noted that technology and science were interconnected, stating, “as you go through the years, you find that technology starts to improve, and the findings are becoming more advanced”. Raquel provided a simple explanation, saying that she learned that technology “can come in many forms”.

**Nature of science.** TCs were asked to identify anything they may have learned about the nature of science. Quite frequently, they cited its historical connections to its environment and surrounding social aspects.

Mae believed the nature of science was “cool”. She recollected the history of DNA and its use in law enforcement to support this, explaining,

It was cool to see how things linked together. It was cool that within that same decade [of] someone discovered DNA fingerprinting ... they were able to arrest some murderer because his DNA was at a crime scene.

Similar to her response related to what she learned about science and scientists, Marni built on her response by indicating that the nature of science was interdisciplinary and, in many senses, ubiquitous and inevitable in how it operated in its social environment. She clarified,
You are automatically linking up things together, whether it be social issues or history or just emotions, you can connect it with different things ... It permeates everything. It is an art. It’s both masculine and feminine. It is in everything, and we have to start viewing it as that, because it is accessible. It’s not something to be afraid of. It’s something to actually realize that it’s there in your life.

Similarly, Raquel also felt that the ability to form these connections between science and the world it was an important takeaway from making her digital timeline. She stated,

It was good to make the connections between what was happening in the real world at the same time as scientific discoveries ... making the links between social and just scientific things.

Additionally, Nina took away a similar learning experience from examining the nature of science, describing that she “really got to know the different scientists, the backgrounds, the inventions or discoveries and how they have helped us now in the 21st century”. Alanna also established the connection between science and historical and social contexts and offered her insight, communicating that “a lot of the developments that happened in science had to do with the time era they were in and what’s needed for that time era”. Giulia singled out the nature of science during the time period she was responsible for in her digital timeline and noted she was surprised and unaware of the lack of representation in science, historically.

Gurpreet came to realize that the nature of science was, in a way, based on philosophy, explaining that scientists had to work with their own theories that would inform their understanding of science. She continued by saying their theories would undergo evaluation and re-evaluation as time went on and more advancements were made.
Comparisons between paper-based and digital-based timeline formats. In general, TCs felt that digital formats could provide more for their timelines than paper-based formats. Nina felt that digital timelines offered more and identified the supplementary details she was able to add to her timeline by stating,

I threw in some videos that you wouldn’t be able to throw in a paper format. [As well as] lots of pictures. And just to cover that 100 years, I do not think you would really be able to represent that on a paper format because of how rich our presentation was …

Giulia also felt that she was able to add more to her timeline and mentioned that the software she used allowed for her final product to look more professional and illuminating for her peers as she was able to supplement her work with sounds, images, and media. Likewise, Marni commented on the numerous possibilities that digital timelines enable in terms of how to present information, stating that,

You can see it as the big thing and you can go into it, into certain points, or you can go through it linearly. There’s so many ways of doing it, you don’t have to go searching a million places for pictures and trying to find the words to describe the words that is better to be heard or to be seen, you can actually can integrate it in digitally.

She continued by saying that much can happen in a time period that it may be overwhelming; therefore, pictures and videos can help present large quantities of information in a way that is interpreted far better by the audience.

Gurpreet discussed the practicality of information sharing as an advantage in favour of digital timelines over paper-based formats. She elaborated,
Especially with what [I] used with TimeToast for my bio-timeline, you got to see everything ... so, basically, that was a lot better than flipping through pages or looking at a poster.

Similarly, Alanna commented on the practicality of digital timelines by discussing how simple it was for timelines to be altered, changed, updated and maintained when they are created digitally, noting that the same cannot be said for paper-based timelines as they require changes to be inputted manually. For Mae as well, she posited that the role of digital technology meant that TCs did not have to be particularly artistic or skillful to create high quality work, insisting that the technology made it fairly simple. These sentiments regarding practicality were corroborated by Raquel, who believed the digital technology aspect helped to simplify the process of making a creative project.

**Does the format affect motivation?** Giulia believed that the motivation of students would be affected by using digital technology to create timelines, citing that technology is helpful to student learning and may allow students to reach new levels of successful outcomes, such as those related to achievement.

Marni shared that the format of the assignment motivated her to get ahead with her work and not procrastinate, stating,

Even knowing how to use [the digital timeline software] now, I still would have started up sooner because you’re able to find so many different things to include, because you can include so many pictures and visuals and audios and video files, I think it makes the research process more fun, because you can go back to it all the time and you can change it up.
She added that had she used a Bristol board, she would have spent more time making changes and perhaps would have had to start over, which would have discouraged her from completing the assignment.

Alanna recollected an assignment her mentor teacher had given to students where they were tasked with using digital literacies to create a presentation about a specific animal, its ecosystem, and the places it lived around their world. She explained what students from previous years had not been able to do with paper-based formats, stating,

It was a small assignment, but they were putting all these pictures, putting all this animation, putting all this information into it. My mentor teacher even commented that he never saw such great work come out of that class.

Nina also talked about the change of formats as a source of motivation, saying students “would want to do it more so than getting a Bristol board and looking for pictures and cutting and pasting”. Mae also assessed working with Bristol boards to be more difficult for students, because they would have been tasked with having to do more work and spend more time working than what they would have when using digital technologies.

Gurpreeet believed that the format could be both positive and negative toward affecting motivation of students. On one hand, she looked at the prospect of working online as a potential distraction for students; however, she also acknowledged that a better understanding of technology could be transferable into creating a better timeline.

Raquel voiced her opinion in favour of digital formats and pointed out the limitations with Bristol boards: “with a digital sort of format, you can really do whatever you want with it”.

**Does the format affect engagement?** TCs believed the digital formatting of the assignment impacted how engaged they were with the assignment itself. Raquel stated,
I found myself exploring a little bit more than I might have otherwise, because it was kind of cool to find new videos or new photos, whereas if I was just drawing it, I probably wouldn’t bother.

Alanna offered thoughts and agreed that engagement was catalyzed via the assignment, explaining,

I was actually very engaged with it, and because I didn’t know much about it, I was still trying to learn things, so I was clicking on a bunch of buttons and trying to see what everything did, and even for the website, when we were introduced to the website, … I didn’t know anything about it, and I was clicking on a whole bunch of different links and trying to make different colour and add different types of pictures to it.

Later, she concluded by saying that her experiences with using this particular set of digital literacies would be something that she would try to emulate in her classroom as a teacher.

Marni felt the assignment affected her engagement because she enjoyed the “playing” aspect of experimenting with new technology to try new ways to improve her project. Gurpreet also recognized the “fun” aspect that came with a digital formatting, elaborating,

[we were given] the option of having videos or having links, and that was more fun to do, I think. In terms of paper, you would just have to copy and paste certain events and descriptions which we were kind of already doing, but I think incorporating the links, the different songs or having videos and stuff like that, I think that was more fun.

Nina felt the format was conducive to her engagement because it allowed her to learn about the software which she found “exciting”. Similarly, Giulia felt the assignment catered to the “imagination” of TCs and added that she felt the format promoted learning.
Marni commented that, while she enjoyed both paper-based and digital-based formats, she especially felt engaged with her digital timeline because of how simple it was to make revisions, as well as how the digital technology could factor into enhancing her timeline presentation.

**Coursework**

The digital timeline served as an example of a digital technology that influenced TCs, who are the focus in this thesis. While discussion stemming from surveys and interviews has had a role in outlining the interests and opinions of TCs towards digital timelines, it is equally as imperative to showcase examples of digital timelines that TCs created. By analyzing examples of their digital timelines more closely, it allows for clarity and contextualizes the discussion of digital timelines that TCs shared in their interviews. Providing examples of digital timelines also allows for illustrating their pedagogical value, as well as their potential as digital resources that are capable of promoting beneficial learning outcomes, fostering engagement, and impacting students and teachers’ attitudes towards digital technology and digital literacy.

**Example 1**

Example 1 was made using Prezi and embodied a traditional structure in the way that it was designed and presented. In Figure 17, the TC opted to create the timeline by following traditional and familiar linear structure in its design, displaying chronological events from left to right.
Figure 17. Overview of a digital timeline created in Prezi.

An example of a TC’s approach to documenting scientific discoveries is shown in Figure 18. There are sequences of events that are displayed within a small time period (1909 and 1912). The most prominent discovery shown is the confirmation of the chromosome theory related to gene inheritance that was discovered in 1910 (top). Below (bottom left), the node on the timeline features a brief but detailed description of that scientific discovery. Specifically, it provides a background on the scientist and their discovery, as well as an explanation as to how the discovery contributed to confirming the chromosome theory. The text portion of the node is highly supplemented; there are surrounding images of the scientist and their team, as well as a link to an interactive game about gene inheritance in relation to the scientist’s discovery of chromosome theory. The interactive game, Inheritance, is an important feature of the digital timeline as it functions as a multi-purpose tool that works to enable engagement and interest from the audience, while also reinforcing understanding of the information being shared about the scientific discovery and the scientists responsible for the discovery. This demonstration is an example of one of the disparities that TCs believed existed between paper-based and digital-
based timelines. While paper-based timelines are capable of being just as descriptive as digital-based timelines, they are unable to enhance additional tools for conveying understanding and constructing knowledge through the use of media components, such as videos and DVGs, like digital-based timelines are able to.

The remaining image (bottom right) documents the events of the Titanic in 1912. Similar to the node about the chromosome theory, there are images and a video (a clip from the Titanic film) to situate the text, demonstrating a method to interweave culture and media with history. While the events of the Titanic are not a scientific discovery, while having much less to do with science, they are an example of an important event in history that occurs during this specific designated time period from 1909–1912. It demonstrates that scientific discoveries, such as the chromosome theory of gene inheritance, do not occur in isolated moments of time; rather the nature of science and scientific discoveries happen simultaneously while human beings and other aspects of cultural life (i.e., commercial transportation, consumer transportation, etc.) are creating histories of their own.
Figure 18. Screenshots of events in timeline (1900-1929).

Example 2

In another example, a digital timeline is portrayed through a unique visual format, displaying chronological events in a counter clockwise direction, while nodes are also increasing in size as the timeline ascends in years, from 1990 through 1996 (Figure 19). Though these timeline features may be miniscule and somewhat arbitrary, they are evidence of the active expression, artistic autonomy, and creativity being used to display and share information that can potentially appeal to audiences, showcasing the breadth of possibilities that TCs had when constructing their timelines. As well, in this creative digital format, nodes are structured to be far more detailed and descriptive regarding the scientific discoveries being discussed. This is an
example of how TCs were enabled to offer more, as alluded to in their interviews. Much like Example 1, there is a plethora of images, videos, and digital resources that are featured throughout the timeline that contribute towards a more holistic and complete understanding of the information being presented. At the same time, attentiveness from the audience is achieved through multiple learning avenues by offering different multimodal components to match differences and nuances in learning tendency preferences, literacy, and disciplinary interest.

![Figure 19. Overview of a digital timeline [Biology 1990s] created in Prezi.](image)

An example of a highly descriptive node about genetic mutation is shown in Figure 20. The TC elected to discuss the first clone of a mammal, Dolly the Sheep, as the significant scientific discovery in 1996. More than just listing the scientific discovery with a brief description, the TC included information that discusses the process of cloning itself, subsequent applications of cloning with other mammals since 1996, as well as the ethical considerations that have arisen due to the nature of cloning and the matter of moral acceptance for humans to do so. With the ethical implication of cloning in mind, the TC has also included theoretical questions to
provoke the audience (i.e., Would human clones have equal human rights?), which means that beyond presenting the timeline, the TC is prepared to engage in a discussion or a debate to further involve their audience with their presentation as a way of supplementing their work and going beyond constructing knowledge.

The TCs notes that the discovery itself – Dolly the Sheep – is named in reference to the famous singer and actress, Dolly Parton. Although this may be seen as nothing more than trivia, in actuality, it strengthens the notion that science is reflective of the society in which it resides. Similar to Example 1, events of the Titanic and the confirmation of the theory of gene inheritance occurring around the same time period, the example of Dolly the Sheep indicate that advancements in science occur concurrently with other cultural aspects of its environment. In this example, science not only occurs simultaneously with other socio-environmental aspects, but also intersects and is influenced by cultural aspects (i.e., music, film, etc.) as the discovery is named in reference to popular culture.

Figure 20. Screenshot of a scientific discovery (1990-1996).
Example 3

The digital timeline displayed in Figure 21 was created by a TC using Tiki-Toki software which specializes in allowing users to create highly detailed, informative, and professional-looking timelines to present to their audiences. In Figure 21, the screenshot displays the overview of the timeline and demonstrates how it is visually formatted. The timeline is formatted to look like a traditional timeline, however, rather than having the nodes link to scientific discoveries or inventions, the nodes are focused on the scientists themselves. Through the Tiki-Toki software, the TC is able to pinpoint a specific date along the time grid to plot each event on the timeline, enabling the timeline to appear clearer and more organized for the audience. This capability is not only advantageous in increasing the overall authenticity of the information being shared as it identifies the exact date for each discovery, but also allows the TC to reconceptualize how they use their digital timeline, such as using it as a tool to facilitate storytelling.

Figure 21. An overview of a digital timeline created in Tiki-Toki.
In Figure 22, there is a focus on the event located on the timeline that investigates Abdus Salam and his contributions to the theory of unified electromagnetic interaction. Salam’s discovery is briefly outlined, explaining how his theory came together and the implications of the discovery. Then, Salam as a scientist is thoroughly unpacked. The digital timeline provides information about Salam’s education, his places of work and study, as well as other important details, such as his professional accolades. The TC also included an overview of the political and social climate that Salam was living within during the time of his scientific discovery, mentioning key events that affected Salam’s career and the nature of his discovery, such as his defection from Pakistan in 1974. As additional resources, the TC provides a hyperlink that redirects the audience into a Wikipedia article where they may read and learn more about Salam and his life if they wish to do so. The TC also includes a video that provides a quick overview of Salam’s career.

**Figure 22.** In-depth view of a node describing a scientific discovery.

Example 3 reframes the idea of what it means to construct knowledge and convey understanding. Just as TCs talked about the excitement, curiosity, and motivation to engage in research and allocated more time towards finding resources to supplement their work (as a result of using digital-based methods) in their interviews, what they are referring to is demonstrated and showcased in their scientific timelines. The layout of Salam’s discovery, as well as the other
scientific discoveries that are documented in the timeline, exemplify how text and digital components come together to thoroughly engage the audience as information is shared. Audiences are able to navigate entries on the timeline in a clear manner and are able to do so through learning avenues that are tailored to their preferences.

In summary, the relationship between TCs and the digital technology in their lives and their digital technological experiences was demonstrated across several data sets. Findings from survey data outlined general positive feelings indicating TCs’ interest in and willingness to employ familiar digital technology in practice, which was also corroborated by interviews and coursework. Findings from interview data indicate that while TCs were open to experimenting and learning new technologies, they still preferred to use the technologies that were familiar to them, as demonstrated by four of the seven TCs in their choice to use PowerPoint and Prezi over timeline-specific technologies. Nevertheless, even though interviews indicated a preference for familiar technology, TCs also identified other possible reasons for their selection of digital technologies, such as how straight-forward new technology may have been to learn, or accounting for the extent to which certain technologies could assist them in creating a project that would meet their own learning needs and goals. For example, some digital timelines articulate that TCs wanted to mobilize knowledge. This was evident based on the extent of how informative their labels and descriptions may have been regarding their scientific discoveries. On the other hand, some TCs preferred to create projects that may have been visually appealing and stimulating for their peers based on some of the themes, graphics, formatting, and design in their projects. Therefore, while there may have been commonalities among TCs in how they elected to choose what digital applications they used, the rationale behind what types of technologies TCs used ultimately varied on an individual basis.
Analysis and Discussion

After having had an opportunity to examine quantitative and qualitative data extracted from surveys, reflections, interviews, and coursework, the findings can be used to form key discussion and analysis to address the research questions. The main research question sought to understand the ways in which digital technologies affected TCs on a number of fronts, including engagement, achievement, their ability to personalize learning, and their attitudes toward digital technology and digital literacy. Findings related to quantitative data were reported through the use of tables and graphs, while findings from qualitative data were thematically coded to draw upon patterns that emerged from TCs’ responses. To triangulate data from surveys and interviews, examples of coursework were discussed as well. In the following section, I discuss the findings in light of the literature and implications for practice.

Attitudes towards digital technology and digital literacy

It became apparent that the basis for TCs developing positive attitudes towards digital technology and digital literacy were related to or contingent upon how familiar, straightforward, and simple it was for them to learn certain digital technologies during their course and their practicums. However, their tendency to favour familiarity did not necessarily imply that TCs exhibited any form of reticence or aversion towards new or unfamiliar technologies. Given their prior understanding and experiences with digital literacies and technologies, a few TCs felt eager to experiment with new digital technologies, especially technology they used in coursework for creating their digital timelines. TCs’ willingness to engage with unfamiliar technology is highlighted by Buzzard et al. (2011) as a modern expectation from students of their teachers, which underpins the extent of how important and pivotal it is for TCs in this study to have exhibited these attitudes as a result of their digital technological experiences. Additionally, TCs
believed that digital technology and digital literacy presented far more advantages to teachers and students than disadvantages which signified a favourable view towards incorporating digital resources in their pedagogy. Based on previously discussed literature about potential advantages of digital technology usage, especially pertaining to, for example, increased learning motivation (Ebrahimzadeh & Alavi, 2017; Narayanan, 2017), and expansion of knowledge capacities (Gee, 2012a), it demonstrates the importance and rationale behind why TCs would or should frequently employ digital technologies as a means of impacting the learning processes of their students.

**Familiarity**

TCs were more likely to willingly incorporate and use digital technology when they were familiar and comfortable with the digital resources at hand. For example, when TCs were asked to rank their level of comfort with certain educational technologies and uses of technology, they indicated they were most comfortable with mainstream options, such as completing online quizzes, using Google Docs, and using student response systems. In examining other, less popular choices, such as creating animations, using publishing programs, and even creating digital stories (which was quite similar to the type of assignment they had with creating digital timelines), their comfort level was ranked comparatively lower. This finding, as it pertains to TCs’ attitudes and approach towards digital technology, helps to inform the growing notions around what it means to be digitally competent in a society and how familiarity may factor into one’s level of digital competence. In the context of education, therefore, where digital competence is shifting towards a general teaching competence (DeCoito, 2018; Krumsvik, 2014), it becomes apparent that competent teachers are well-trained and familiar with the technologies they are expected to use and are more equipped to incorporate their digital skills in their pedagogy as a result (Pedro et al., 2014). In referencing Figure 9, which highlights
frequency of use of a certain set of digital applications and features, results indicated TCs most frequently used features that required little time, little effort, and low amounts of digital proficiency to perform, such as taking pictures or recording videos. More nuanced uses of digital devices, such as maintaining a blog or producing a podcast, were hardly – if at all – performed by TCs, perhaps alluding to the implied increased labour and complexity involved with performing either of those functions.

However, the creation of digital timelines was another example of TCs engaging with digital literacies because of prior familiarity and comfort with specific digital resources in terms of actually constructing their timelines. As indicated in their interviews, four of seven TCs used either Prezi or PowerPoint to create their digital timelines rather than attempting to use timeline-specific software like Tiki-Toki or TimeToast. The popularity among TCs in selecting the two presentation-based mediums was expected as previous studies indicated that PowerPoint and Prezi were instrumental in promoting long-term learning benefits and knowledge acquisition, respectively (Chou et al., 2015), while students generally found Prezi to provide many benefits to learning (Moulton et al., 2017). Interview recollections suggest that TCs found PowerPoint and Prezi to be fairly straight-forward and simple to navigate. Both programs proved capable in meeting not just the requirements of their assignment, but also towards fulfilling their own personal goals they wished to attain from completing their work.

**Realization and actualization of autonomy**

As TCs retained a fair degree of control over what digital technologies they could use, this served as a positive notion since it signified that TCs could approach their work using digital technologies and resources they most preferred. Just as Davis and Ash (2011) outlined in their study of students being provided the opportunity to exercise their autonomy, the TCs were also
provided similar opportunities to select the digital technologies and applications they felt would best assist them in their coursework. Findings from surveys, such as the reflective questions that are documented in Table 3, alluded to this sense of autonomy that TCs felt they had with digital literacies. As TCs ‘disagreed’ on the statement that their digital timelines limited how many topics or interests they could cover, this implied that they had creative control to a certain extent. This further allowed them to incorporate an array of topics or functionalities in their final product, enabling them to create an assignment that could include any creative aspects of their choosing, whether through videos, pictures, interactive games, or other elements.

Table 4 also demonstrates that TCs exhibited a sense of collective agreement in terms of access to needed equipment and software to create their digital timelines, confirming they had a plethora of resources and materials to use at their disposal. Interview data recollections were also consistent in demonstrating that TCs had control over aspects of learning, specifically with their timelines. Just as Giulia indicated in her response about which software she used for the digital timeline, she qualified her answer by stating that through TimeToast, she was able to organize and thoroughly detail every event and point on her timeline, which enabled her to create her timeline to most accurately reflect how she wanted it to look. Similar to Bradley and Evans’ (2017) explanation of the capabilities that digital timelines offer, Giulia’s anecdote is one example where a digital timeline is able to meet the personal needs and learning goals of a TC. Likewise, recalling Thiry et al.’s. (2013) explanation that among many capabilities, timelines can enable personalized approaches from its creators, is further evidence that TCs were given the opportunity to demonstrate autonomy in their assignment. Finally, it is through examining screenshots of timelines where it becomes evident that timelines were very unique and tailored specifically to match how TCs wanted to present them.
Perceived advantages versus disadvantages

In discovering that coursework, as well as teaching practice, could be improved with digital technology, findings which discussed the perceived benefits of digital technologies, and how advantages outnumbered disadvantages, could therefore be interpreted as evidence of positive attitudes towards digital technology. This is consistent with, for example, Alvarez et al.’s. (2013) findings about the use of digital enhancements (IWBs, digital pens) in the classroom. In their study, digital enhancements were pivotal in affecting cognition literacy and increasing proficiency in subject content. In their interviews, TCs indicated perceived benefits of incorporating digital literacies and using digital technologies manifested through many forms, such as (i) simplifying aspects of teaching and learning; (ii) changing the perception of subject content (i.e., “cool”) and making it more engaging for teaching and learning; (iii) reinforcing knowledge and understanding of subject content; (iv) providing real-world applicability for students; and (v) providing teachers with more options for assessment measures. In comparison, perceived drawbacks mostly pertained to (i) potential distractions; (ii) lack of accessibility to digital technology; and (iii) insufficient training and competence with digital technology, the latter two of which were more structural and out of the control of teachers than they were individual issues. Of course, much like Kong (2014) articulated, there is sufficient need to address teacher training with digital technology, which may inform why these drawbacks exist.

Personal achievement

Beyond Raquel mentioning in her interview that she felt her timeline was successful due to the mark she received from her course instructor, there was no other data that highlighted, much less displayed, any sort of statistical achievement of TCs, such as grade levels or academic
marks. Therefore, the gap between experiences with digital technology and statistical achievement was not directly addressed in this study.

Nevertheless, TCs were asked about the success of achieving goals and outcomes through digital timelines. As an alternative method to examine achievement, data centered on the evidence of learning, as well dialogue centered on learning (specifically questions about what TCs learned from constructing timelines), could inform how experiences with digital technology affected this focus. In other words, this would entail exploring the demonstration of knowledge discovery, knowledge construction, knowledge retention, and applicable learning.

In examining survey findings, Figure 8 demonstrates that TCs “agreed” with many of the statements related to learning, especially with statements that discussed the evidence or tangibility of learning, potentially referring to their digital timeline as an example of evidence of their learning through their coursework. In many respects, the creation of digital timelines represented a tangible product. As previously discussed, it allowed TCs to apply prior knowledge of science, as well as the opportunity to apply their digital competencies, to create a project that would unite both aspects of their overall knowledge and skill set and enable them to learn more about science and digital technology. Similarly, Figure 10 indicates that TCs showed strong agreement with the statement about educational technology helping them to succeed with coursework, which once more, is corroborated by the literature related to technology assisted learning and pedagogy (Deitrich & Balli, 2014, Paz-Albo, 2017; Remon et al., 2014).

Table 4 provides an in-depth view into reflective statements about learning that is based on the experiences of creating digital timelines. As the findings suggest, TCs exhibited agreement on many statements pertinent to achievement, such as “I can apply what I learned from creating a biology timeline to my learning”, “While creating my biology timeline I applied
digital technology in my learning”, “While creating my biology timeline I learned to organize and present ideas”, “Biology timelines can showcase learning”, and “I was able to include a sufficient number of topics in my biology timeline”. Many of these statements allow for inferences to be made about the extent to which TCs constructed knowledge, conveyed understanding, and retained learning experiences, perhaps to the same extent that Dennis and Bellshaw (2013) identified in their study of digital timelines and the propensity to assist in student learning.

Findings from the interviews related to TCs’ learnings in specific areas, including science, technology, and the nature of science in society revealed many different remnants of what they learned. For example, when asked about science and scientists, TCs specifically noted that (i) science did not occur in a vacuum; it was often contextualized, interdisciplinary, and based on the needs of the society; and (ii) scientists of non-dominant positionalities (such as women and people of colour) were often underrepresented. Examples of recollections like these demonstrate that TCs started to understand their subject speciality through different lens that they could incorporate when they taught science in their future careers. Finally, conversations about perceived successes related to goals and outcomes fostered through experiences with creating digital timelines also helped to demonstrate the range of successful outcomes of TCs, such as learning new knowledge, contextualizing newly found knowledge, and disseminating knowledge, which are related to achievement and digital literacy.

**Personal engagement**

Based on the findings, the role of digital technologies in affecting engagement of TCs was quite prominent. When TCs were directly asked if the digital format of the timelines contributed to their engagement, many of them agreed and provided unique rationales as to why this was the
case. To reiterate, TCs talked about experiences with digital technology using adjectives such as “fun” and “cool” to describe the process of creating their digital timelines and becoming more acquainted with digital literacy, as well as knowledge of science and their specific science time period. It was noted that using digital literacies was similar to “playing” in the sense that TCs were able to experiment with different technological and creative possibilities during the process of creating their timelines. In reflecting on studies of engagement (Bonvin & Sanchez, 2017; Perry & Steck, 2015), it is evident that use of digital technological elements can be drivers of not just social engagement, but subject content engagement as well.

Moreover, TCs’ account of digital formats affecting motivation could also be interpreted as a precursor for fostering engagement. Recall that TCs listed numerous factors that contributed to promoting student motivation, which included the affordances of digitally based formats, the added benefits they could use to enhance work, and the opportunity to learn more and gain knowledge. Many of these factors could reasonably function vis-à-vis with stimulating engagement. In conjunction with Thomas (2017) on the differences in fostering engagement between digital textbooks and print-based textbooks, it is unsurprising that TCs found their digital alternatives to be more interesting and to have described them using adjectives like “fun” and “cool”.

Examining the digital timelines themselves also provides evidence as to how TCs fostered engagement amongst their peers. For instance, in observing the screenshots of the digital timeline in Example 1, there are numerous features on display that enhances the text, such as the images, videos, and the DVG, which all possess the potential to act as sources of engagement with the audience. The DVG in particular is able to shift the landscape of learning and embody adjectives like “fun” as the roles of the audience digress to them playing to understand the
content rather than listening or visually following along, both of which are comparatively more passive methods of participation and engagement. Arguably, all of the examples of digital timelines highlighted the emphasis on fostering engagement as one of the goals of the assignment, as TCs went beyond just providing the required information on scientific discoveries. All of the examples show the use of images, colours, visual transitions, the role of popular culture and society, and other accompanying factors and features as a way to contextualize science and in doing so, draw the attention of fellow TCs to engage with their digital timelines. In recalling the literature on the important elements of digital storytelling (Chigona, 2012), digital timelines do not differentiate a great deal from digital stories, which highlights the importance of TCs making their product not only rich in content knowledge and information, but rich in presentation and design as well.

**Ability to personalize learning**

The process of personalizing learning can be viewed as a process to meet personal needs (The Next Generation Blended Classroom, 2016) and can also be understood as the authorization of freedom in the classroom (Deed et al., 2014a). By acknowledging that TCs had control over the digital technologies they could choose to use in their coursework, it highlighted the potentiality of them being able to facilitate – albeit somewhat indirectly – the process of personalizing learning for future students they would teach in their careers as they could, in theory, structure their teaching practices to meet student needs. It is positioned that TCs would address personalizing learning indirectly because TCs did not share any particular anecdotal accounts of where they had an active role between themselves and their students, and how they focused on meeting specific needs and goals through tailoring their pedagogy and learning processes accordingly. Rather, through the understanding that there existed differences in
preference among themselves and students towards different types of digital technologies, learning preferences, and literacies and modes, among other factors, TCs possessed the ability to personalize learning through encouraging the use of autonomous learning practices related to digital literacy and digital technology. To recall, TCs only briefly touched upon these experiences in their practicums during their interviews, such as the recollection Alanna provided about her mentor teacher and the assignment about ecosystems that they had given to their students. In other words, there were no formal conversations that discussed their practicum experiences in full detail, where they could elaborate or identify how they could modify learning to fit the personal needs and goals of their students.

Therefore, beyond their ability to personalize their own experiences of learning through their assignment, data could not inform any substantial findings about TCs’ abilities to “truly” personalize learning for other peers or students. The data was flexible in identifying experiences where TCs could personalize their own learning experiences, such as making educational experiences more open, accessible, and free of restrictions. As well, data could also inform this notion of personalized learning by further examining how TCs assisted themselves in their own learning experiences.

As highlighted in Figure 8, TCs’ agreement with a group of statements about learning and assessment could indicate TCs’ recognition of their own process of personalized learning. Many of these statements can be interpreted as examples of student assessment, personalized feedback, and deeper learning, all components of what Evans et al. (2014) describe as parts of the composition of personalized learning. In particular, statements such as “I collect and refer to samples that show quality work”, “I self-assess and set goals”, “I revisit and reset the criteria as I learn more”, and “I collect evidence of my own learning”, all demonstrate active roles in
learning, as well as emphasizes the responsibility and individuality of the TCs taking control of their learning. In acknowledging this, statements that are deliberate in referencing evidence and samples of learning (such as those above) are ultimately demonstrated in the actual process of creating digital timelines and in the final product. As examples, digital timelines demonstrate that different pathways of learning can be accessed through touching upon multiple factors – be it through creative formatting, or linking society, environment, and real-world applicability to subject content – and exemplifies the unique approaches taken by TCs to showcase how they navigated their understanding of science, as well as how they attempted to share knowledge with their peers (who had their own specific learning preferences).

Findings from interviews highlighted many of the experiences where TCs tied their use of technology to learning that was tailored to their own preferences. Just as TCs discussed, they were able to select the software they wanted to use in order to build their timelines to match their own preferences. Multiple TCs confirmed that they were able to incorporate any selection of elements at their disposal, such as visual formatting templates, accompanying videos and images, and even some of the content itself, so that their timelines could effectively and authentically communicate the full scope of the historical period of science they were tasked with presenting to their peers and fellow TCs. Coursework data exemplified the unique, personalized approaches that TCs undertook when creating their timelines. As digital timeline examples displayed, none of the timelines were the same in how they were designed and presented, strengthening the notion that TCs were able to personalize how they approached sharing what they learned about science in their selected time period.
Conclusion

In recognizing the need for teachers and educators to develop themselves as facilitators and promoters of 21st century learning, and in doing so through embodying digital competencies and proficiency with digital technology, this study aimed to explore how individual competencies and aspects of young educators were affected. Findings suggest that it is evident that TCs are aware of the value of digital literacies and digital technology towards enhancing and transforming schooling experiences for themselves and their students. Propensities and motivation to use digital competencies, as well as engaging with digital technologies, can be consistently predicted when teachers are familiar with the types of resources and tools they are engaging with and when they can perceive what they are using as straight-forward, simple to use, and without accompanying difficulties. It should not be a surprise, therefore, that commonly owned devices, such as smart phones and laptops, are frequently relied upon to deliver, assist, and enhance learning experiences by catering to differentiations in learning, engagement, and individual preferences of students.

For teachers, the challenge is not so much to simply continue working with digital technologies to heighten schooling experiences; it is to do so by venturing into learning about and engaging with more complex, intricate, and unique forms of digital technology. Digital timelines have demonstrated their capabilities in how they are able to affect approaches to learning and pedagogy and how the actualization of using them as a digital technological resource can impact teachers and students. An appropriate next step, therefore, lies in working with new digital technologies and continuing to explore how teachers respond and subsequently, think about incorporating new tools and resources in their careers.
Limitations

Although the data at hand proved to be informative and sufficient in addressing the aims of this research, it must be acknowledged that, due to it being secondary data and not primary data that was collected for the specific aims of this research in mind, some aspects of the analysis, therefore, could have been further substantiated and legitimized. To clarify, consider that in addressing digital technology affecting achievement of TCs (as one example), research relied solely on both statements and evidence of learning to provide insights on this focus. However, additional data, such as academic marks and grade levels of TCs, may have been very effective in triangulating the analysis and authentically unpacking the understanding of the relationship between digital technological experiences and TCs’ academic achievement. As well, in focusing on timelines specifically, formal comparisons between paper-based timelines and digital-based timelines could have also provided a selection of data that, beyond substantiating current findings, may have potentially rendered contrasting findings and reshaped the understanding of how TCs were impacted.

Earlier, there was discussion centered on contextually relevant experiences with digital technology in schooling as a gap in literature. Specifically, it was noted that studies centered around digital technology usage in Canadian contexts were sparse, especially with teacher candidates as the main focus group. While this study attempted to address that gap and was largely successful in informing how Canadian TCs were impacted by their experiences with digital technology, it was only one formal glance at this relationship. The experiences of TCs at this university, while unique and enlightening in their own right, are not necessarily representative of the experiences of TCs from other Canadian universities, from other academic disciplines, from other specialized subjects, and from other designated grade levels.
Future Research

As this study attempted to communicate the relationship between digital technologies and how they impacted TCs’ attitude towards digital technology, personal engagement, processes and outcomes of achievement, and ability to personalize learning, future efforts should aim to isolate one of the four foci and explore it more intimately rather than focusing on multiple aims simultaneously, for further validity and reliability. More rigorous and aim-defined studies may produce more candid and authentic findings.

While digital timelines were the selected form of digital technology in focus for this study, future studies should aim to position other, specific forms of digital technology to explore how they may impact TCs, and specifically their digital competencies, in technology enhanced environments. That is not to imply that digital timelines no longer require subsequent or further focus; rather, examining other forms of digital technology may work to corroborate and build upon findings from this study regarding digital competencies of TCs, or may challenge findings to probe new queries about the relationship between teachers and digital resources they use.

Concluding Remarks

In closing, this study has provided the opportunity to reflect on the working status of modern teachers through the digital technological experiences of a select group of TCs. In this study, TCs’ experiences was demonstrated to be largely informative on a collective basis to pinpoint how and why teachers may employ digital technology in their classrooms and how it may affect numerous aspects of their practice (such as engagement, achievement, and personalized learning). It is essential to remember, and ultimately recognize, that teachers as individuals have personal experiences, preferences, and beliefs regarding their approaches to teaching, learning, and pedagogy. Even though conclusions resulted from analyzing secondary
data of a study in teacher education, I contend that future research directions should persist in exploring and engaging with TCs and teachers in classrooms and schooling environments that embrace digitally enriched learning spaces and promote technology-enhanced teaching and learning.
References


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Appendices

Appendix A: Technology Usage Survey

Date: ________________ Age: ________________ Gender: M [ ] F [ ]

Educational Background: ___________________________________________

Subject Speciality: ________________________________________________

Please complete the following questions about your experiences with technology. There are no right or wrong responses.

1. How often do you access online course material? [ ]
   8 = More than once a day
   7 = About once a day
   6 = Two or three times a week
   5 = About once a week
   4 = Two or three times a month
   3 = About once a month
   2 = Two or three times a semester
   1 = Never or almost never

2. How often do you use York University computer labs? [ ]
   8 = More than once a day
   7 = About once a day
   6 = Two or three times a week
   5 = About once a week
   4 = Two or three times a month
   3 = About once a month
   2 = Two or three times a semester
   1 = Never or almost never

3. Which of the following portable devices do you own, and which would you like to own?

   OWN [ ] OWN [ ] WOULD LIKE TO [ ]

   Netbook
   GPS (Global Positioning System)
   Smart phone (e.g., iPhone, BlackBerry)
   Cell phone (e.g., no online capabilities)
   Digital Media player (e.g., iPod)
   Laptop
   Notebook/Tablet (e.g., iPad)
   eReader (e.g., Kobo, Kindle)

4. How much would you be willing and able to pay in monthly connection charges for a mobile device such as the ones listed in the previous question?
   [ ] Less than $20/month
   [ ] $20-39/month
5. Many contemporary Web-based technologies allow users to participate actively in the creation of online content. About how often do you do each of the following?

1 = never
2 = 1-5 times a week
3 = 6-10 times a week
4 = more than 10 times a week

[ ] Create or contribute to a blog
[ ] Create or contribute to a wiki
[ ] Create a podcast
[ ] Upload a video to share with others
[ ] Upload photos to share with others

6. Online educational technology can be used in any of the following three ways:
   • to support a course delivered totally online;
   • to replace some face-to-face time with time spent working online; and
   • to supplement an unchanged face-to-face course.

   Approximately how many courses (including your current courses) have you taken that were delivered in each of these ways?

1 = none
2 = 1-5
3 = 6-10
4 = more than ten

7. A growing number of universities are considering increasing the number of courses they offer fully online. What is your preference about taking fully online as opposed to face-to-face courses? Use the numbers 1, 2, and 3 to rank each mode of delivery.

   Supplemented [ ]  Hybrid [ ]  Totally Online [ ]

8. Many universities are currently exploring “class capture” systems which record and make available online the audio and/or visual components of a face-to-face class. How useful would you find it to have available, for the classes you take, each of the following types of class capture materials?

   (Scale: Very useful = 4, Moderately useful = 3, Slightly useful = 2, Not at all useful = 1)

   [ ] Audio-only captures
   [ ] Audio plus projected materials
   [ ] Audio-only plus projected materials plus video of instructor

9. Educational technology is designed to improve the learning experience for students in a variety of ways. Please rate each of the following statements about the role educational technology has played in your learning experiences.

   (Scale: Strongly agree = 4, Agree = 3, Disagree = 2, Strongly disagree = 1)
Online library resources and services have helped me succeed in my coursework.

The advantages gained by using educational technologies outweigh the disadvantages.

Most of the educational technologies available to me have been easy to learn.

In general, educational technology has helped me to succeed in my coursework.

Because of educational technology, my instructors demanded more work from students.

Because of educational technology, the teaching in my classes was more student-centered.

Because of educational technology, my instructors demanded higher quality work from students.

Educational technology has made it easier for me to see how the ideas I learn in class apply to real life.

I will have a better portfolio to show future employers as a result of using educational technology.

10. Which of the following best describes your preference with regard to the use of educational technology in your courses? Check as many as you like.

[ ] I prefer taking courses that use no educational technology.
[ ] I prefer taking courses that use a small amount of technology.
[ ] I prefer taking courses that use a moderate amount of technology.
[ ] I prefer taking courses that use a large amount of technology.
[ ] I prefer taking courses that use technology exclusively.
[ ] No preference.

11. How useful have each of the following educational technologies been to you in your coursework? (Scale: Very useful = 4, Moderately useful = 3, Slightly useful = 2, Not at all useful = 1)

[ ] Email (e.g., to communicate with instructors or other students)
[ ] Instructor’s lecture notes or PowerPoint slides online (e.g., for downloading prior to or after class)
[ ] In-class electronic presentations
[ ] Visualization tools, simulations, or animations (e.g., to help you learn difficult concepts)
[ ] Moodle course Web site
[ ] Class captures (recordings of in-class activity posted online for later review)
[ ] Blogging tools (e.g., to keep a class-related journal)
[ ] Chat tools (e.g., to brainstorm with several other students at once)

12. Please rate your level of comfort in each area
DIGITAL LITERACIES AND COMPETENCIES OF TEACHER CANDIDATES

(Scale: Very comfortable = 4, Comfortable = 3, Uncomfortable = 2, Very uncomfortable = 1)

[ ] Taking quizzes online
[ ] Using student response systems
[ ] Using Google docs (or other Google apps)
[ ] Using Web-based threaded discussion tools
[ ] Creating Prezis
[ ] Creating Digital Stories
[ ] Using chat tools
[ ] Editing video with multimedia programs such as iMovie or Premiere
[ ] Creating audio with multimedia programs such as SoundForge
[ ] Creating animations with programs such as Flash
[ ] Using desktop publishing programs such as PageMaker
[ ] Using digital games for teaching/learning
[ ] Creating websites
[ ] Creating YouTube Videos

13. To what degree has each of the following factors been a problem for your use of educational technology in your courses?
(Scale: Large = 4, Moderate = 3, Small = 2, Not a problem at all = 1)

[ ] Network/Internet problems (e.g., network slowness)
[ ] Instructors not using educational technologies well
[ ] Problems with my computer
[ ] Problems using Internet sites
[ ] Amount of time needed to learn educational technologies
[ ] Amount of time needed to use educational technologies

The following are short answer questions. Please elaborate on your responses.

14. Many students use social networking sites (such as Facebook, MySpace, Bebo, Orkut) to keep in touch with friends and acquaintances. If you use such a site, how would you feel about efforts to integrate that site into your academic experience – seeing announcements from your classes in Facebook, for instance?

15. Many students use digital technology during their classes for purposes that may or may not be related to the class itself (e.g., sending text messages, reading Web pages, checking social networking sites like Facebook). Do you use technology in this way, or have you seen other students do so? If so, what are your thoughts about this practice?

16. In the past, some students have expressed the concern that their professors do not make good use of educational technology. How could your professors improve their use of educational technology in the classes you have taken?
17. Should technology be integrated into educational programs? Why?

18. What types of technology would you like to see integrated in your program? Why?

19. How will you integrate technology in your teaching practice?

20. What are some technologies that you have been introduced to in the program that you were not aware of before? Were these technologies useful?

Are you interested in participating in an interview (face-to-face or telephone) to further explore your views on implementing technology in science education?

Yes [ ] No [ ]

If you answered yes to an interview, please leave your name, email address and a telephone number where you would like to be contacted. I appreciate and value your input.

Name: ______________________

Email: ______________________

Telephone: __________________

Thank You!
Appendix B: Biology Timeline Reflections

Name ____________________________ Date _______________ Male [ ] Female [ ]

PART A: Survey – Reflecting on the Biology Timeline

<table>
<thead>
<tr>
<th>REFLECTING ON A BIOLOGY TIMELINE</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Disagree nor Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. While creating my biology timeline, I learned about technology.</td>
<td></td>
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<td>2. While creating my biology timeline, I learned to use new equipment.</td>
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<td>3. While creating my biology timeline I improved my use of familiar equipment.</td>
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<td>4. While creating my biology timeline I learned to use new software programs.</td>
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<td>5. While creating my biology timeline I improved my use of familiar software programs.</td>
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<td>6. While creating my biology timeline I learned to organize and present ideas.</td>
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<td>7. While creating my biology timeline I learned to apply technology in my learning.</td>
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<td>8. While creating my biology timeline I learned to evaluate my learning.</td>
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<td>9. Digital biology timelines are more powerful and convenient than traditional poster formats.</td>
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<td>10. Biology timelines can showcase learning.</td>
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<td>12. I can apply what I learned from creating a biology timeline to my learning.</td>
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<td>13. I had difficulties related to equipment</td>
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<td>14. I had difficulties related to software when creating my biology timeline.</td>
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<td>15. I felt time constraints when creating my biology timeline.</td>
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<td>16. My biology timeline was too limited in the topics that were covered.</td>
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<td>17. My lack of knowledge with certain aspects of technology was a problem when creating my timeline.</td>
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<td>18. This assignment needs to have more direct guidance throughout the process.</td>
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<td>19. It was challenging to select the content of my biology timeline.</td>
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<td>20. Sufficient class time was allotted for working on my timeline.</td>
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<td>21. I had adequate access to equipment when creating my biology timeline.</td>
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<td>22. I was able to include a sufficient number of topics in my biology timeline.</td>
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<td>23. I was able to be creative in my timeline.</td>
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<td>24. I did an adequate amount of reflection on my development as a learner during the timeline.</td>
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<td>25. My biology timeline looks professional.</td>
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<td>26. Guidelines for the biology timeline assignment were clearly stated.</td>
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<td>27. There were sufficient opportunities to receive feedback on my timeline from my peers.</td>
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<td>28. There were sufficient opportunities to receive feedback on my timeline from instructor.</td>
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<td>29. There were sufficient opportunities to view my peers' timeline during the</td>
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<td>30. The biology timeline assignment should be optional.</td>
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<td>31. I had adequate access to needed software when creating my biology timeline.</td>
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<td>32. I had adequate access to needed equipment when creating my biology timeline.</td>
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<td>33. I would like to publish my biology timeline on the Web.</td>
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<td>34. I am more likely to use technology in my future employment because of my experiences making a biology timeline.</td>
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<td>35. I found the biology timeline assignment to be collaborative.</td>
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<td>36. I found the biology timeline assignment to be inclusive.</td>
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<td>37. I found the biology timeline assignment to be dynamic.</td>
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<td>38. I found the biology timeline assignment to be inquiring.</td>
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<td>39. I found the biology timeline assignment to be reflective.</td>
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<td>40. I plan to use my biology timeline in job searches.</td>
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<td>41. I do not plan to use my biology timeline in the future.</td>
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<td>42. I had adequate access to technical support when creating my biology timeline.</td>
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</table>
PART B: Exploring the Development of the Biology Timeline

Please respond to the following question about your experience developing the biology timeline.

1. How well-prepared do/did you feel to complete the biology timeline? How well prepared are/were the other students?
2. Did you or your fellow students have problems in putting together the biology timelines? Did this change over time?
3. What kind of documents did you include in your timeline? (check all that apply)
   - Text I copied from another document
   - Word Processing documents that I attached to my timeline
   - Images that I found on the Internet
   - Images that I created myself with a computer graphics program
   - Images that I created myself and scanned
   - Digital photos created with a digital camera
   - Links to other websites
   - Links to a web page I created myself
   - Audio files that I found on the Internet (including music)
   - Audio files that I created myself
   - Video files that I found on the Internet
   - Video files that I created myself
   - Other __________________________
4. What are the advantages or benefits resulting from developing a biology timeline using digital technology?
5. What are the disadvantages or concerns resulting from developing your biology timeline using digital technology?
6. a) What did you learn about science from constructing a biology timeline?
   b) What did you learn about scientists from constructing a biology timeline?
   c) What did you learn about the nature of science from constructing a biology timeline?
7. Do you plan to use your biology timeline after you graduate? How?
8. Do you believe it was worth your time to create a digital biology timeline? Why or why not?
9. On a scale of 1 -10, with 10 being the highest score, my overall satisfaction with my biology timeline was ___. Why did you choose that rating?
10. How would you improve your biology timeline?
11. Comment on any other aspect of the biology timeline that was not covered above.
Appendix C: Biology Timeline and Assessment

Name __________________________________________ Date ____________________ Male [ ] Female [ ]

Please complete the following statements about your Biology Timeline assignment.

1. Is the concept of biology timelines new to you?
   [ ] Yes [ ] No

2. Were you given an introduction to biology timelines and how to use them?
   [ ] Yes [ ] No

3. If you answered ‘yes’ to question 2, please rate the following two statements:
   (a) At this point, I feel comfortable. The introduction was adequate.
   [ ] Strongly agree [ ] Agree [ ] Neither agree nor Disagree [ ] Disagree [ ] Strongly disagree
   (b) At this point, I feel comfortable with the level of support that was available to me for the biology timeline.
   [ ] Strongly agree [ ] Agree [ ] Neither agree nor Disagree [ ] Disagree [ ] Strongly disagree

5. Do you have an effective way to deal with the following? In each case, answer with either “yes”, “no”, “somewhat”, or “not sure”.
   a. Present your coursework/thoughts/ideas ___________
   b. Represent your growth over the duration of the course ___________
   c. Think about what you are learning and how you would like it to develop ___________

6. The following are features of the science methods course. Please rank each based on how important you felt the feature was to you throughout the course.

   (1 = not important, 2 = somewhat important, 3 = not sure, 4 = important, 5 = very important)
   a. Having all coursework in one location accessed through one interface ______
   b. Being able to share your experiences (coursework, reflections, thoughts) with your peers ______
   c. Being able to view your teacher feedback, personal reflections and coursework ______
   e. Being able to show potential employers actual examples of your growth and development (this could involve showing them actual pieces of coursework – timelines, website resource, etc.) ______
   f. Being able to participate in learning communities with your peers (e.g., class forum) ______
   g. Sharing your experiences and resources with fellow students (concept activities, etc.) ______
   h. Being able to share and discuss any problem you may be having on a particular topic ______
   i. Using a portfolio of evidence (Moodle) built up over the year to demonstrate your competence in a subject ______
The following statements cover how the Course Director involved you in assessment for learning.

1. The Course Director involves students in ongoing assessment for learning.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

2. The Course Director summarizes the learning that students are expected to accomplish.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

3. The Course Director collects and reviews samples and models to show what the learning looks like for students of a particular age range.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

4. The Course Director thinks about what kinds of evidence students could produce to show they have learned what they needed to learn.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

5. The Course Director ensures the evidence of learning is valid and reliable by collecting evidence over time so emerging trends and patterns can be identified.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

6. The Course Director uses classroom assessment information to fine-tune instruction and the learning environment for students.
   [ ] I don’t know [ ] Not at all [ ] Some of the time [ ] All or most of the time

Please respond to the following statements about learning and assessment:

1. I am able to articulate the learning goals
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

2. I collect and refer to samples that show quality work.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

3. I am able to describe what evidence of learning might look like.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

4. I set criteria with my Course Director to define quality learning.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

5. I have time to learn.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

6. I receive and give specific, descriptive feedback as I learn.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time
7. I debrief my learning with my peers and others.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

8. I self-assess and set goals.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

9. I revisit and reset the criteria as I learn more.
   [ ] Not at all [ ] Some of the time [ ] All or most of the time

10. I collect evidence of my own learning.
    [ ] Not at all [ ] Some of the time [ ] All or most of the time

11. I present evidence of learning to others and receive feedback.
    [ ] Not at all [ ] Some of the time [ ] All or most of the time

12. I am fully involved in the assessment process. I am working harder and learning more.
    [ ] Not at all [ ] Some of the time [ ] All or most of the time
Appendix D: Developing Teacher Candidates’ Digital Competencies

Note: Only the following questions are referenced in this thesis: (1, 2, 3, 4, 5, and 7)

Interview Protocol

Interview #: ___ Grades: _______ Subject Specialty: ____________________

The following questions are designed to explore your experiences with digital literacies in and out of education.

1. Briefly describe your understanding of digital literacies.
2. Have you experienced/implemented digital literacies in coursework and/or teaching prior to this science methods course? Explain.
3. Do you feel that digital literacies should be incorporated in all levels of science teaching? Why? How should they be incorporated?
4. What are the benefits of incorporating digital literacies as perceived by (a) students and (b) teachers?
5. a. What are perceived drawbacks/obstacles to implementing digital literacies with students? How can these be addressed?
   b. What are potential obstacles to implementing digital literacies in the classroom? How can these be overcome?
6. The Biology Timeline assignment required you to utilize any digital application to represent your understanding of biological discoveries in an assigned time period.
   a. What period were you assigned?
   b. What application did you choose to represent your Biology Timeline? Why did you choose this application?
   c. Do you feel that you were successful in achieving the desired outcome (constructing knowledge and effectively conveying your understanding) for the timeline? Why or why not?
   d. In the development of the biology timeline, what did you learn about:
      1. Science
      2. Scientists
      3. Technology
      4. Nature of science
   e. How do paper-based formats compare to digital formats for constructing and displaying a biology timeline? Explain.
   f. What aspects are conveyed in your digital timeline that are not as easily conveyed in a paper-based format? Explain.
   g. Does the digital format of this assignment affect a student’s motivation to construct a biology timeline? If so, how?
   h. Did the format affect your engagement with the biology timeline assignment? Explain.
Ethical Approval

Dear Dr. John DeCosto,

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above. This approval is conditional on submission and acceptance of NMREB Continuing Ethic Review.

This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Document Type</th>
<th>Document Date</th>
<th>Document Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview Protocol</td>
<td>Interview Guide</td>
<td>10/02/2020</td>
<td>1</td>
</tr>
<tr>
<td>Survey Protocols</td>
<td>Paper Survey</td>
<td>10/02/2020</td>
<td>1</td>
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</tbody>
</table>

No deviations from, or changes to the protocol should be initiated without prior written approval from the NMREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCP2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00005941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Kelly Patterson, Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Curriculum Vitae

Name: Stefano Vacca

Education:
M.A, University of Western Ontario, Faculty of Education, 2020
B.Ed, York University, Faculty of Education, 2018
B.HRM, York University, Faculty of Liberal Arts and Professional Studies, 2018

Professional Accolades and Development:
Presenter, Canadian Society for the Study of Education (CSSE), 2020 (postponed)
Presenter, Robert MacMillan Symposium in Education (RMSE), 2020

Professional Experience:
Student Teacher, St. Theresa of Lisieux Catholic High School, 2017-2018
Student Teacher, St. Augustine Catholic High School, 2015-2016